

American Society For Quality Control



ABSTRACTS OF PAPERS

**THIRD ANNUAL CONVENTION
IN CONJUNCTION WITH THE
THIRD NEW ENGLAND
QUALITY CONTROL CONFERENCE**

"Controlled Quality is Good Economy"

**Copley Plaza Hotel
Boston Massachusetts
May 5 and 6, 1949**

FORWARD

At a preliminary meeting of the Convention Committee held in Boston, November 8, 1948, it was decided to print in booklet form abstracts of all the papers to be presented at the clinics of the Third Annual Convention.

These abstracts are as the name implies, short outlines of the papers to be presented and will serve to acquaint the reader with the subject matter of the various clinics.

The committee wishes to extend to the authors of these abstracts, thanks and appreciation for their cooperation in sending in their papers in time for printing.

Proceedings Committee

*J. J. Ferri
F. C. Heyl
E. C. Harrington
M. M. Newcomb*

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OF
QUALITY CONTROL

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CONTROL OF QUALITY IN COMPONENT MANUFACTURE

By: Dorian Shainin *

A circuit breaker prevents damage to electrical circuits when something goes wrong. Control charts when properly set up, work similarly only the task is involved - a number of things represent potential trouble (*assignable causes of variation*). The chart, fortunately, is simpler and more reliable than a mythical circuit breaker, containing electronic circuits, solenoid relays, etc., to perform these tasks but sometimes malfunctioning.

Control charting was not always simple (*when sample standard deviations needed computing - now replaced by estimation from range developed by Messrs. Tippett and Pearson*) and needs further simplification. Sample averages are employed, being particularly sensitive to certain significant individual-value distribution changes regardless of these distributions' shapes. In a shop, however, the needed division takes time and leads to error. Certain shops accordingly use samples of 5, then double each sum, marking off one decimal place. While this helps, a problem remains - workers comparing control limits with specification limits and thus feeling tolerances are cut.

RECOMMENDATIONS FOR BUILDING QUALITY INTO THE PRODUCT

First, use sum and range charts. The sums vary as the averages, and dividing and specification limit comparisons cease.

Next, when introducing control charts, too much attention cannot be paid to arranging that the operator himself gets readings and plots points. Keeping the inspector away provides strong benefits of single responsibility and economy. The extra man's wages are unnecessary; the scrap, rework, and arbitrary tool-life runs (*often too short*) are more effectively eliminated by the man's complete familiarity with immediate operating situations. This natural, psychological situation creates new found interest in the formerly monotonous routine. It often results in even significantly increasing production rates. Although chart keeping is extra work, in no case has our operators' production rates dropped for longer than an introductory week. The secret - provide a taste of the right recipe and the operator sells himself..

Recommendation number three: remember the quotation "Good, better, best - never let it rest 'til the good is better, and the better best". The "good" is starting new charts with special reject limits (*the extreme control limits for sums*

that would keep a normal distribution of individuals just inside specification limits) serving as preliminary guide lines for the operator's first 10 sums. Following 10 samples, the "better" is calculating approximate control limits from from average range. The "best" is recalculating limits when 25 samples are available. Never let the reject limits "rest". Remove them directly after 10 samples, since they do not represent process capabilities.

Recommendation four concerns frequency of sampling. To my knowledge this is currently an arbitrary decision in shops using control charts, when it should be based on probability concepts. It is entirely reasonable to lean on Mr. H. F. Dodge's "Sampling Plan for Continuous Production". This scheme, for given risk values, determines the number of successive pieces which must be acceptable prior to enjoying a given sampling frequency. While sampling, any defectives encountered require 100% checking again until the originally required successive number is cleared to permit resumption of sampling. Since the control chart is a "variables" application, taking advantage of the situation, one notes the distance between the 3 standard deviation limit (individuals), estimated from recent sampling experience, to the nearest specification limit. If the original distribution changes between sampling periods, a portion of the distribution could occupy this region between the two described limits. The smallest portion here to introduce pieces beyond specification would be created by a standard deviation increase. The tail area of this distribution cut by this region can then represent the continuous plan's AOQL, affording limiting protection beyond specification of about 1 1/2 pieces per thousand. This protection can be eased, resulting in decreasing sampling frequency.

Chemical solutions, medical production cultures, and even automatic machinery, all can benefit from a special sampling frequency. When a batch or run in itself shows very little variation, control is desired over variations among batches, settings, etc.

A reading occurs daily or at such relatively infrequent periods compared to product output. Much success attends plotting individual points, accompanying a moving range chart (sample size, two - range between each last reading and its predecessor). The average range, from at least 10 range points, is converted to a conventional range control limit, and to control limits for individuals for an individual chart.

* B.S. - Massachusetts Institute of Technology - Chief Inspector - Hamilton Standard Propellor Co.,

INCOMING AND BATCH INSPECTION

By: Mr. Dorian Shainin *

When a doctor samples your blood, you both are confident his analysis will properly reveal the condition of all your blood; you know the mixture is homogenous, sampling gets each element proportionately as in all the blood.

Development of an industrial sampling counterpart for each specification to determine "condition of the blood" of a batch of material introduced a new philosophy to current inspection thinking. We say "new" because most plants employ either 100% inspection practices for at least all critical specifications for complete protection, or some popular attribute type sampling plans. Here selected risk levels reflect management opinions regarding semi-critical or non-critical specifications, or sometimes levels are established more scientifically by balancing cost of inspection against handling cost of defective material eluding sampling. Certain "variables" sampling techniques are published, but generally they are very involved, difficult to administer and assume sometimes unjustifiable lot characteristics. Basically, such attribute and variable plans determine whether there is sampling evidence that lot quality differs significantly in percent defective, average or spread from specification requirements. Maintaining selected limiting risk levels is achieved, on paper, by screening (100% inspection) lots which fail the sampling.

Because increasing national experience shows 100% inspection not even approaches 100% effectiveness, this new basic philosophy, similar to the medical blood check, becomes interesting. After caring for all situations (*including non-normal distributions*) characteristics of incoming or batch inspection, we had a simple combination of variable sampling and certain supplementary attribute techniques called the Lot Plot plan. It is already popular in other concerns: brushes, scales, chemicals, aircraft engines, and governors.

This plan applies "Lot Limits" to the observations, then separately determines lot disposition by these limits' relation to specification limits, the relationship being translated into terms which permit application of practical knowledge concerning use of the product coupled with, for defective lots, probability concepts defining the degree of random assemblies. Necessary screening is not therefore dictated by the scheme's statistical design, but rather would rise only from economic considerations concerning the immediate need for some of the product. Such seldom used

sorting usually is required on only a portion of the lot. Rejected material is safely left for the original supplier to screen or scrap, optionally, without fear he may successfully return it untouched to get by another time.

Devised primarily for practical economic administration in a factory, the plan features a constant 50 piece sample size, determines from the first 5 pieces the sensitivity needed for gaging equipment, employment of special techniques for obtaining truly random samples and a very low overall risk level - low enough for us and certain other aircraft manufacturers to replace 100% inspection for extremely critical requirements. We enjoy from 3 to 50 times less risk than from 100% inspection.

OPERATING CHARACTERISTIC CURVE FOR LOT PLOT ACCEPTANCE PLAN, N OF 50

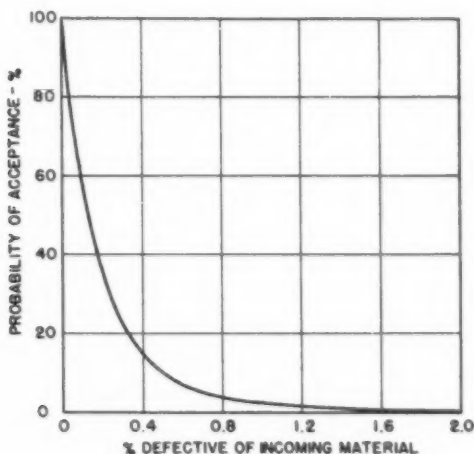


Figure 1

See Figure 1. An attribute plan, sample size 500, would approximately duplicate this curve, but ten times the inspection reintroduces inspector fatigue difficulties.

Figure 2 illustrates the form employed as a work sheet, inspection record, medium for showing or plot (*frequency histogram*) of the lot which develops (*the shape and position of which clearly determined which of certain special analysis methods apply*), and Salvage Order for determining disposition of lots containing defectives. Each carbon copy, ideally a real quality control vehicle, is transmitted to the vendor. Pictorial data illuminate any needed corrective action.

The "Lot Plot" can serve industries not having such critical safety requirements. Permissible use of not tight AOQL's economically invites attribute sampling. Samples containing more than allowable defects require 100% screening. Usually the lot size is large, so why not next prepare a Lot Plot? The resultant estimated percent defective can be compared with allowable AOQL; also extent of error determined. These factors reveal whether screening is necessary. Small standard deviations, with improper average positions are not uncommon.

SHAININ

L.P. NO. _____

HAMILTON STANDARD PROPELLERS LOT PLOT AND SALVAGE ORDER

HSP 9009

VENDOR X.Y.Z. Co., Rochester, NY PART NAME Retainer PART NO. 55037
 P.O. NO. 243524 R.S. NO. 277574 QUANTITY 1400 DATE 2-17-48
 SPEC. 687 +.000 O.D. INSPECTOR VJ SAMPLE SIZE 50

	-10	0	10	20	
	-9				
	-8				
	-7				
	-6				
68625	-5				
30	-4	0			
35	-3	2	7		
40	-2	3	10		
45	-1	1	1	3	4
68650	0	1	2	4	6
55	1	2	4	6	7
60	2	3	4	5	5
65	3	4	5	6	7
70	4	5	6	7	8
68675	5	6	6	8	
80	6	8	10		
85	7				
90	8				
95	9				
68700	10				

NO.	SUM	AVG.	RANGE
1	+2	2.2	7
2	-5	2.0	5
3	-5	2.0	5
4	-1	2.8	3
5	+5	2.0	2
6	+9	2.6	4
7	-2	2.4	6
8	+4	2.8	9
9	-1	2.2	4
10	+2	2.4	7
11			
12			
13			
14			
15			
TOTALS		+14	52
AVG. OF 10		2.2	5.2
THESE VALUES		3R	1.58
IN CELL UNITS		30	6.76
CELL INTERVAL			.00005
DIM. DISTANCE		R TO L.L.	.00034

DISPOSITION	% EXTENT	ADDITIONAL SAMPLE DATA
ACCEPT (CO. INSP.) <u>Shainin</u>	BEYOND H.L. <u>O.K.</u>	ADDITIONAL SAMPLE OF _____ SHOWS
SALV. ACCEPT (HSP SALV.) <u>Shainin</u>	BEYOND L.L. <u>O.K.</u>	PIECES BEYOND TEST CELL
GOV'T. INSPECTOR <u>VJ</u>		

REMARKS- _____

Figure 2

Often the Lot Plot confirms need for screening, but a restraining check has been placed on the fatigue bugaboo which affects 100% inspection. The approximate percent defective to be found is known. Moreover a Lot Plot gives the vendor necessary corrective action information.

Reduction of 29% in receiving inspection cost and to zero, or rejections from assembly or service, of improperly manu-

factured parts with 31,500,000 specification requirements processed during eighteen months' Lot Plot operation measure its success in our plant.

- * B.S. - Massachusetts Institute of Technology - Chief Inspector - Hamilton Standard Propellor Co.,

NOTES:

OVER-INSPECTION AND HUMAN ERRORS OF MEASUREMENT

By: O. H. Somers*

A basic weakness in many manufacturing plants is the use of 100% manual inspection to sort acceptable pieces from defectives. Although this practice has a hoary tradition supporting it, it is actually a most ineffective instrument. Innumerable investigations have shown that inspectors doing this type of work will generally discover only that percentage of defective work which their experience has taught them provides the greatest job security. A dial indicator manufacturer for example, found that on small pieces having a total tolerance of 0.0003" an average of 17% defective material was passing 100% manual "inspection". Boredom and distractions are the principal reasons for failure of this technique. Process correction and sampling are the cures.

Sometimes, because of life-hazard for example, 100% inspection or sorting cannot be avoided. Where the volume or nature of the job prohibits the use of automatic equipment, 100% manual inspection is mandatory. The only way to overcome the influence of boredom and distractions is to use a properly designed, systematic check inspection plan. In such a plan random samples of the work of each inspector are taken and re-checked by a supervisor. If A is the number of defects removed by the original inspector and B the additional number of defects missed by the original inspector but found by the check inspector, then the ratio $\frac{A}{A+B}$ is a good measure of the effectiveness of the original inspector. This measure can be charted on a p type chart, with upper and lower control limits. An average value for p of 0.97 or 97% is used as a standard by one bearing manufacturer. Inspectors falling consistently below this average are transferred to other work and lose the 10 cents per hour premium paid to inspectors.

Instrumental and human errors of measurement are common causes of defective control of quality. Frequently ignored entirely, these errors can actually constitute a large part of the total tolerance and thus produce a misleading quality analysis of the product. The normal combined human and instrument standard deviation of one inch micrometer calipers, for example, is about 0.0003". The use of these instruments for tolerances under 0.006", therefore, introduces an error in size discrimination exceeding 16%. Similarly the combined standard deviation for 1" plug or snap gages is of the order of 0.0002". These instruments cannot thus be used safely for tolerances below about 0.004", without exceeding a reasonable error. In general it can be suggested that instruments should be selected whose combined human and

instrument standard deviations do not exceed 5% of the total process or tolerance spread.

* - Quality Control Engineer -
Western Printing and Lithographing
Company

NOTES:

SOME RELATIONS OF QUALITY CONTROL TO PERSONNEL

By: Paul Peach*

In setting up control charts quality control supervisors tend to rely heavily upon the psychological pressure exerted by charts upon operators. This approach gives an early gain but loses in the long run, since it places workers and control charts in a position of antagonism. Early gains tend to vanish when the novelty wears off, especially if (as often happens) production foremen make little or no use of the charts.

Modern factory workers tend to be cynical about the motives of management. If they are given a swimming pool, they do not feel there is any occasion for gratitude; they assume that somebody in authority has figured out that the swimming pool will increase profits (or income tax deductions). Nevertheless, workers will accept the swimming pool and use it, since clearly they have nothing obvious to lose. So also with better tools, better working conditions, and so on; the worker wants these things because they make his work easier or increase his earnings, not because they increase or improve his output.

Acceptance of new methods must rest upon personal benefits to the user. He will accept the new methods and the attendant benefits, even though there is a concurrent benefit to management. Quality control should seek and emphasize the the personal benefit angle. Mere improvement of quality is in itself of little interest to the worker, and cannot be relied upon to sell quality control.

In one factory in Pennsylvania workers on a piece rate were not paid for unusable pieces. After each operation the scrap was sorted out and deducted from the worker's production. This sorting was itself costly, and not worth while if the fraction defective were only about one or two percent. Accordingly the rule was made that if a worker succeeded in keeping his fraction defective at or below 1% for a reasonable time, his product would henceforth be accepted on a sample basis, and he would be penalized only for defective pieces found in samples. The sampling plan thus became a device by which the worker could be paid for defective work. It appealed, not only to his cupidity, but to his vanity also, since in his eye it amounted to "putting something over" on the management.

In a plastics factory in the south quality control personnel watch both quality and quantity of production at various operations. But whereas the quantity records are gathered

and charted in a matter-of-fact way, the quality checks are dramatized. Whenever possible, the check is made on material before it comes to the operator, shifting the emphasis from "policing A" to "protecting B". A of course gets the same protection on material coming to him. Operators are encouraged to request quality checks on doubtful material. The whole attitude of quality control is that bad quality is usually the fault of machines or materials, thus giving personnel a face saving escape. In this plant operating personnel look upon the quality control division as their allies, and corresponding success has followed.

Not everybody is selfish and greedy, and certainly many people can be reached, at least for a time, by appeals to patriotism, pride of workmanship, and similar lofty motives. Nevertheless, there are few people indeed, in factories or elsewhere, who are not influenced to a considerable extent by self-interest. An appeal to this motive is almost sure of success.

** Associate Professor - Department of Experimental Statistics
University of North Carolina*

NOTES:

SPECIAL ENGINEERING APPLICATIONS OF STATISTICS

By: Paul Peach*

In an address to the Industrial Applications Section of the Royal Statistical Society in London, Mr. W.A. Swan said in part: "...during the war the emphasis was on quality control charts. This was rightly so, because it was the mass production of ammunition to which statistics was mainly applied, and the quality control chart suited very well. For steel work...charts seldom seem...useful... 75% of the jobs of the (Statistical) section (of United Steel) are correlation-regression studies, usually multiple... We use the "t" test and analysis of variance... analysis of covariance...".

Mr. Swan's experience in the steel industry has, I suppose, been duplicated in all industrial fields in which there have been persons with adequate statistical training. Nevertheless, we have not exhausted the control chart and other simple tools such as frequency diagrams. One North Carolina factory (making women's nylon hose) recently presented me with two examples.

Present methods of production give many long and short stockings -- more than can be readily marketed. A simple method was desired for estimating proportions of total product of various lengths. We could of course use the mean and standard deviation in connection with a table of the normal integral, but this would involve first making a test of normality, then computations with squares and square roots. The simple solution is to use arithmetic-probability graph paper. Given a set of measurements, it is necessary only to calculate and plot cumulative percentages. The points turned out to be reasonably close to a straight line, which could be fitted by eye; all desired estimates could be read from the graph.

A second problem from the same factory dealt with training personnel. Sewing the seam up the back of a stocking is a skilled job that takes about six months to learn, and some people never learn it. There has been no reliable means of separating the untrainables except to keep on trying to train them until the facts were obvious -- usually after three months or so. Clearly it is desirable to weed out the misfits as early as possible. The solution of this problem was a control chart for \bar{x} , but of unusual design. Its center line was a rate-of-learning curve based on past records of the training department, and measuring average daily production. There was no upper control limit. The lower control limit was based on standard deviations observed at various stages of the training period; it was close to the center line at both ends and quite far away in the middle. It was

a one-sigma limit, and three failures were taken as enough to disqualify a trainee, subject to the judgement of the training foreman. This simple device has cut the period of uncertainty from three months to less than six weeks.

Another factory wished to test whether playing music during working hours would increase productivity. The complication here was a considerable normal variation in productivity from week to week, or even from day to day, and the solution involved several advanced ideas: design of experiments, analysis of variance, and orthogonal comparisons. The design chosen was a Latin square, with weeks as rows, days as columns, and programs as treatments; there were four different musical programs and one "silent". In the analysis we calculated the components for music vs. no-music, programs against each other, and incidentally the effect of days and weeks. The outcome was that all four programs were about equal, and that no-music gave significantly (5% level) higher production than music. The difference, though significant, was small; but enough to show a balance in favor of no-music.

Another study dealt with the effect of vision on productivity. The problem was to examine productivity data of a series of worker for whom visual acuity measurements were available, to test whether those with better vision tended to produce more. The complication here was variable age and experience; an older worker might have weaker eyes but produce more because of longer experience. The statistical method employed was that of multiple regression, which enables us to tell whether age, experience and visual acuity give a better basis for predicting productivity than age and experience alone. (Partial correlation might have been used, but would have been somewhat less informative.) It turned out that each additional year of experience was worth about 1% in added productivity (all workers tested had at least several years' experience) while each year of age carried with it an average loss of about 1/2% -- net gain for the worker who gains a year's experience and grows a year older at the same time is thus 1/2%. Eyesight did not seem to matter. This does not mean that eyesight is not important (naturally, none of the workers had badly defective vision) but only that so far as this group of employees was concerned, the age factor satisfactorily accounted for the observed difference without bringing in special eyesight measurements.

So much for recent examples from my own experience. Any advanced worker in industrial statistics could add many more. There is no statistical tool that does not have industrial applications, because there is no field of science that is not related to industry. Those statistical workers will go

farthest and accomplish most who acquire as many tools as possible, and cultivate skill in their use.

** Associate Professor - Department of Experimental Statistics
University of North Carolina*

NOTES:

DIAGNOSIS WITH DIAGRAMS

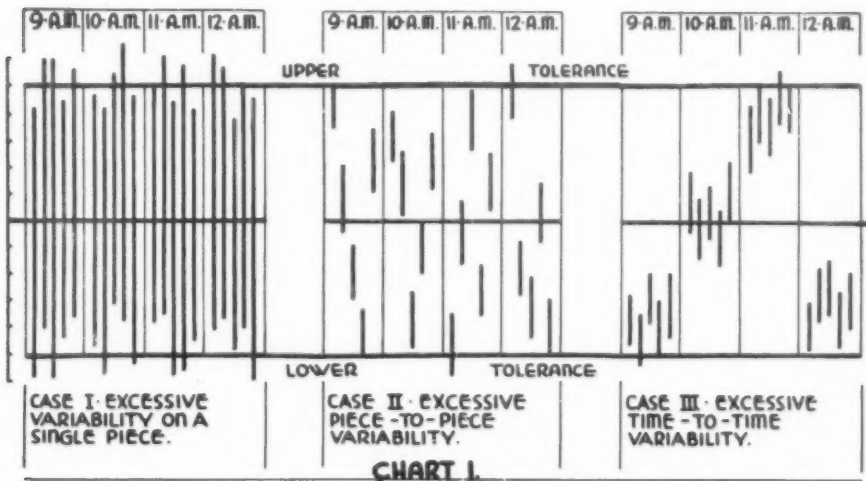
By: Leonard A Seder*

Much of the success of statistical quality control techniques is undeniably attributable to the conciseness and forcefulness of graphic presentation. Similar methods of dramatization are needed to popularize the more powerful statistical tools--such as analysis of variance--since the solution to most quality problems ultimately depends on the principles they embody. This paper covers several examples in which simple diagrams are made to tell an action-compelling story at the operating level. Some are diagrams to aid the quality control engineer in his diagnosis of process ailments: others are data pictures to help an operator decide which of several possible actions will bring his process back into control.

DIAGRAMS TO AID PROCESS DIAGNOSIS

When a process is being observed for symptoms of quality diseases, it is essential to evaluate the several sources of variation which contribute to the overall process variability. In most mechanical processes, these may be categorized as follows:

1. Variability on a single piece.
2. Variability from piece to piece.
3. Variability from time to time.



The relative magnitudes of these three sources may be shown conveniently in a chart like chart number one. Variability on-a-single-piece is represented by a straight vertical line

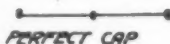
connecting the maximum and minimum measurements of the piece. Lines for five individual pieces, sampled at once, afford a visual measure of Piece-to-Piece Variability and the spacing of these samples over several minutes or hours shows the Time-to-Time Variability. The three charts of Chart number one depict "pure" cases, in each of which one of the three sources dominates the situation, submerging the other two. Equally frequent in practice are cases, shown in the paper, in which more than one source is significantly large.

INTERPRETATION OF CAP DIAGRAMS

FAULT

TYPICAL DIAGRAMS

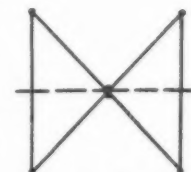
*PUNCH AND/OR
DIE RELIEF*



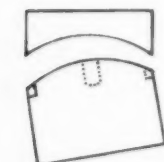
PERFECT CAP



TYPICAL CAP



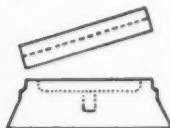
EXCESSIVE RELIEF



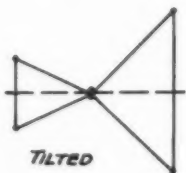
ROLL OVER
(OR MISALIGNMENT)



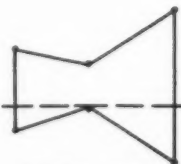
ROLLED OVER
OR MISALIGNED



TILT



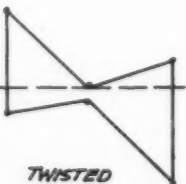
TILTED



TILTED AND
ROLLED OVER



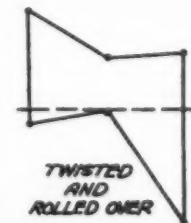
TWIST



TWISTED



TILTED
AND TWISTED



TWISTED
AND
ROLLED OVER

CHART II

Additional examples in the paper demonstrate how a fourth source of variation, such as multi-stations, may readily be added to such a chart.

DIAGRAMS TO AID OPERATOR ADJUSTMENT

The problems of control presented by Cases two and three usually yield to X and R chart treatment. New graphic aids may be advantageously employed for Case one, however, which is often a machine set-up problem.

The technique of Chart number two, for example, was developed to signal to the machine operator the proper adjustment of a press and die line-up in a metal-forming process. The "cap diagram" depicts the distribution of 6 readings of a thickness measurement around the periphery of the pressed piece. Distance from the reference line (in either upward or downward direction) is proportional to excess of thickness over thinnest reading. Each point corresponds to a definite physical position, so that a glance at the pattern immediately reveals which of the three major planal alignments--or combinations thereof--needs correction.

Production use of these diagrams has been eagerly accepted by operators and has been singularly effective in reducing Variability-on-a-Single-Piece to one-half of its previous uncontrolled value.

Another example in the paper shows the use of similar diagrams to perform a graphical analysis of variance on a multi-station, double-bladed broaching machine, resulting in reduction of 60% in total variability.

* B.S. - Massachusetts Institute of Technology
 Process Engineer - General Electric Co., - River Works
 Chief Quality Engineer - Gillette Safety Razor Co.,
 Past Treasurer & President - Boston Society for Quality Control.

NOTES!

PRACTICAL APPLICATIONS OF NEW THEORY: A REVIEW

By: Frederick Mosteller*
John W. Tukey*

Many statistical developments are not used in practice until long after their discovery. Sometimes this happens because the material is written in difficult mathematical language which most users do not have the time or equipment to translate. In other cases the developments are published in journals not ordinarily read by the potential users. For example, a general development in statistics may be published in a journal for geneticists in an article about specialized flora--quality control people are not likely to be aware of such a result. Quality control people have been quick to apply the latest methods which have been brought to their attention, and they frequently ask for and need new and different tools to help solve their more specialized problems.

It is the purpose of the article being abstracted to bring to the attention of quality control personnel some of the latest developments in mathematical statistics which, in the opinion of the authors, may be usefully applied in quality control work. It is hoped that such a reporting job will reduce the lag between development and use of the latest statistical methods in quality control. It must be remembered that most of the material discussed has not been used extensively in practical work. Most of these developments have appeared in articles on mathematical statistics, and their application to quality control work has not been specifically mentioned.

It would be a mistake, however, to assume that mathematical developments have not grown out of quality control work. In our review of this literature it will be seen that some of the mathematical developments have been made by research men in the quality control field working directly on quality control problems, one example of this is the field of process control.

Here we mention only a few of the developments to give a notion of the scope of the paper. We have taken material since 1940, with heaviest emphasis on work since 1945.

A few of the developments are: improvements in the search for the maximum of a function of one or several variables; the use of transformation in applications of the serial correlation coefficient and in the treatment of data arising from counting; the use of order statistics to obtain cheaper information in special kinds of quality control work, particularly destructive sampling; new methods of sensitivity

testing; a new tchebycheff inequality which can be used in the absence of knowledge of the true distribution; new theory puts some of our assumptions about distributions and statistics on safer ground by showing how departures from the assumptions affect our results; non-parametric and distribution-free results for analyzing data quickly without the customary assumptions of normality.

- * *Frederick Mosteller - Professor Harvard University*
John W. Tukey - Dept. of Mathematics, Princeton University

NOTES:

WHAT RISKS SHOULD I TAKE IN SAMPLING INSPECTION

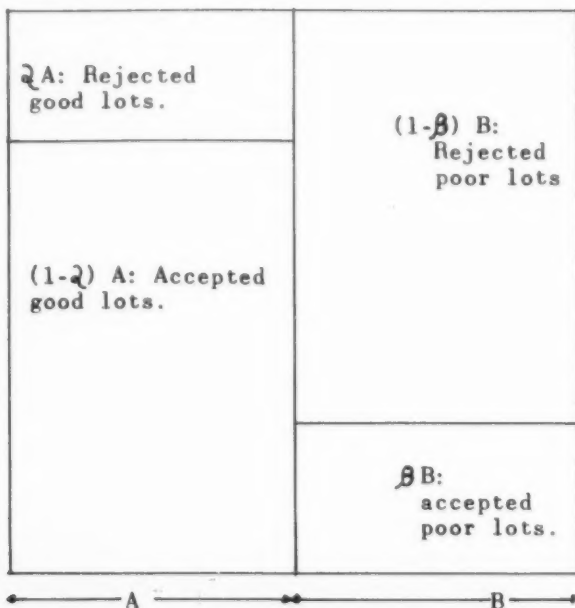
By: F. E. Satterthwaite*

The problem of sampling inspection is the problem of evaluation of risks. The two basic risks are:

1. The risk that an accepted lot will be poor.
2. The risk that a rejected lot will be good.

These risks obviously depend on the number of good and poor lots in the first place. If all lots are good, then all accepted lots are good. Also, all rejected lots are good. If all lots are poor lots, then all accepted lots are poor lots. Also, all rejected lots are poor lots. In between the answers depend on the proportions of good and poor lots submitted for inspection.

Consider a simplified example. Suppose A lots are submitted which have $p_1\%$ defective pieces and B lots are submitted which have $p_2\%$ defective pieces. Then the odds are A to B that a lot chosen at random is a good lot. We can represent this graphically by dividing the area of a square in the proportion, A to B:



Now let us apply a sampling plan with producer's risk, α ,

and consumer's risk, β . Since the producer's risk, α , is the probability that a good lot will be rejected, we have in the upper left the area, αA , representing rejected good lots. Similarly the area βB , represents the accepted poor lots. The odds that a rejected lot is in fact a poor lot are $(1-\beta) B$ to αA . Similarly the odds that an accepted lot is a good lot are $(1-\alpha) A$ to βB . These results are an example of the famous Bayes' Theorem.

It is convenient to think of these results as being obtained through the multiplication of sets of odds. Thus the odds that a rejected lot is in fact a poor lot are:

	Poor		Good
Prior odds	(B	to	A)
Sample odds	$\times (1-\beta)$	to	α)
Combined odds	$(1-\beta) B$	to	αA

The "sample odds", indicate the additional information regarding the quality of the lot which is furnished by the sampling plan. The sample odds depend on whether the sample indicates acceptance or rejection. If the sample rejects the lots, the sample odds are $1-\beta$ to α that the lot is poor. If the sample accepts the lot, the sample odds are $1-\alpha$ to β that the lot is good.

In practice the inspector sets the odds which he would like to have in his favor before accepting or rejecting the lot. He then calculates the producer's risk, α , and the consumer's risk, β which the sampling plan must have if it is to give him the required protection. He then chooses a plan with those risks.

The paper also covers the problem of estimating the prior odds, A to B, that the lot is good. Included is a discussion of how to proceed when the prior information is sketchy or incomplete.

* - Quality Control Engineer - Product Service Division
General Electric Company

NOTES:

PRECISION OF MEASUREMENT AND PRODUCT VARIABILITY

By: Frank E. Grubbs*

An introduction is given to the problem of precision of measurement and product variability. A measurement or observed value is discussed as the sum of two components - one of the true or absolute value of the characteristic or item measured and the other an error of measurement. Thus, a series of n measurements may be represented symbolically by x_1 plus e_1 , x_2 plus e_2 , x_3 plus e_3 , ..., x_i plus e_i , ..., x_n plus e_n where the component x_i is the true value of i th item measured and the component e_i is the error of measurement made on the i th item. The amount of variation in the true value $x_1, x_2, \dots, x_i, \dots, x_n$ is termed product variability, whereas the amount of variation in the errors of measurement $e_1, e_2, \dots, e_i, \dots, e_n$ is a measure of the of the precision of measurement. It is thus seen that in order to have precise measurements, then the variation in errors of measurement of an instrument should be considerably smaller than the variability of the product. Moreover, accuracy of individual measurements will result only when our measurements are precise and our instruments are properly calibrated relative to a standard. The amount of variability or variance in the measured values is symbolically:

$$S_x^2 \text{ plus } 2 S_{xe} \text{ plus } S_e^2$$

where

$$S_x^2 \text{ equals } \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2,$$

$$S_{xe} \text{ equals } \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x}) e_i - \bar{x}$$

and

$$S_e^2 \text{ equals } \frac{1}{n-1} \sum_{i=1}^n (e_i - \bar{e})^2$$

The problem of precision of measurement and product variability, therefore, can be expressed analytically as that of "separating" S_x^2 and S_e^2 , and determining whether S_e^2 is sufficiently small, relative to S_x^2 , to result in the desired precision of measurement for a given problem. The term S_{xe} , known as a covariance, gives a measure of the relation of degree of correlation between the items measured and the errors of measurement. This covariance term is particularly troublesome in the problem of estimating pre-

cision of measurement if it does not average out to zero.

In this paper, the problem of precision of measurement and product variability is approached from the standpoint of using actual data. Techniques involving the use of two or more measuring instruments are discussed for separating and estimating precision of measurement and product variability. In addition, the relation between the problem of precision of measurement and that of determining whether "outlying observations" can be attributed to errors of measurement or, are characteristic of the product is given consideration. Finally, an introductory discussion is given of the general problem which may involve correlation between the errors of measurements of the instruments or operators and correlation between the errors of measurement and the true values of the items measured.

* - Chief Surveillance Branch, Ballistic Research Laboratory
Aberdeen Proving Grounds, Maryland

NOTES:

FURTHER CONTINUOUS SAMPLING INSPECTION PLANS

Based on Random-Order Spacing of Defects

By: Harold F. Dodge*

This talk presents two continuous sampling inspection plans, modifications of an earlier random-order plan published in 1943**, intended for application to a product consisting of a flow of consecutive individual units (parts, subassemblies, finished articles, etc.) or lots. The plans, applicable only to quality characteristics subject to nondestructive inspection on a Go-NoGo basis, are of particular interest to products manufactured by conveyor or other straight-line continuous processes. They provide a corrective inspection with the object of assuring that the average percentage of defective units in outgoing product will be kept down to a prescribed low figure, designated as the AOQL, *average outgoing quality limit*.

The original plan**, here designated CSP-1, involved for following procedure:

- a. At the outset, inspect 100% of the units consecutively as produced and continue such inspection until i units in succession are found clear of defects.
- b. When i units in succession are found clear of defects, discontinue 100% inspection, and inspect only a fraction f of the units one at a time from the flow of product, in such a manner as to assure an unbiased sample.
- c. If a sample unit is found defective, revert immediately to a 100% inspection of succeeding units and continue until again i units in succession are found clear of defects, as in paragraph (a).

This plan, CSP-1, requires reversion to 100% inspection whenever a defect is found. The modified plans CSP-2 and CSP-3 differ from CSP-1, in that, once sampling inspection is started, 100% inspection is not invoked every time a defect is found but is invoked only when a second defect occurs within a prescribed interval following the first defect. Thus a single isolated defect will not call for reversion to 100% inspection. Plan CSP-3 has a special feature to provide protection against a sudden sharp degradation of quality. These plans can be thought of as having a relationship to CSP-1 similar to the relationship between a single sampling plan having an acceptance number of c equals 1 and a single sampling plan having an acceptance number of c equals 0.

A set of curves is given to permit appropriate choices of f and i for a chosen value of AOQL.

- ** H. F. Dodge "A Sampling Inspection Plan for Continuous Production", *Ann. Math. Stat.*, Vol. XIV, No. 3, pp. 264-279, Sept. 1943; *Trans. A.S.M.E.*, Vol. 66, No. 2, pp. 127-133, Feb. 1944.
- * Quality Results Engineer, Bell Telephone Laboratories; Fellow and Chairman Standards Committee, A.S.Q.C.

NOTES:

MOBILIZING FOR QUALITY IN A COMPETITIVE MARKET

By: J. J. Juran*

We are emerging from a national quality spree. Since 1941, though plagued with materials shortages, labor shortages and equipment shortages, we have done a superb production job. But attached to much of that production was the visible tag of high price and the invisible lable of poor quality.

Our shortages are now behind us, but the habits they generated are still with us. We relaxed standards. We used ersatz materials. We put up with subnormal machine maintenance. We handled vendors with kid gloves while kicking our inspectors and customers all over the place. We sanctioned the doing of these things, year after year. To canction them we authorized changes in specifications, practices, routines. For the most part these changes are still on the books. For the most part these practices are still the prevailing practice. For the most part, *the habits of the personnel are still those of low quality and high cost.*

From my observation, there are three general methods being tried by executives to get back to high quality and low cost. Two of these methods are weak extremes.

At one extreme is an eloquent appeal to the personnel, pointing out that competition is here, that costs must come down, that quality must go up. This appeal, however eloquent, is bound to fail because it is not founded on a planned program for action.

At the other extreme is a bits and pieces effort of getting after really bad instances as they rear their ugly heads. This effort is likewise doomed to failure because it is just pecking away at the problem instead of going after basic causes on some organized plan of action.

The third and successful method is to prepare a comprehensive set of objectives, to assign to everyone in the company a part he can play, to provide a scoreboard to measure the progress of the plan, and to supply the necessary stimuli for achieving the objectives. I have in my experience been associated with a number of such plans for action. Their essential elements are as follows:

- a. *Prove to each employee that he has a personal stake in the company's quality reputation.*

This can be done by an internal advertising campaign - posters, slogan contests, reports from customers, articles in the

house organs, moving pictures, anything appropriate for showing a clear connection between the employees personal interests and the quality of the final product. Incidentally, it is hard to surpass one of the slogans developed in Bigelow-Sanford's campaign, "Quality Makes Sales; Sales Makes Jobs".

- b. Compute the "gold in the mine" to demonstrate that better quality costs less.

Find out what is the cost arising from presence of defects - the scrap, reworks, extra operations, discounts on seconds, service charges on guarantees, cost of sorting product when sampling might do, and so on. As often as not, *half of this cost can be eliminated* by a thorough program of modern prevention. The reduction in cost can finance the entire program of quality improvement, with room to spare. The potential improvement is an index of how big a program to launch.

- c. Show each employee how he can personally contribute to better quality.

This means clear specifications of what is wanted. It requires clear instructions on how to run the processes. It requires adequate measurement or standards so that the employee can judge *as he works* whether he is doing the job right. Proper induction of new employees, good training, balanced incentive plans and good maintenance practice are part of this. Competitions and contests are in order to urge the employee to find new ways amid old surroundings to improve quality.

- d. Set up a quality control engineering group.

The supervisors and shop personnel can by themselves make many improvements. But many of the fundamental improvements require extensive fact-finding, trials and experiments, and special analysis of data. The shop personnel have neither the time nor the training to take on these lengthy studies. The budget for the master plan should provide for one or more quality control engineers to meet this need.

- e. Provide for coordination and skilled counsel.

A program like the foregoing demands participation by all major departments - design, production, quality, sales, sales service, purchasing, methods and others. Achievement of high quality at low cost is a *teamwork* job. In my experience, a Quality Committee, with representation from the principal departments is an admirable coordinating device. Where the company has never before embarked on such a program it is well to secure advice from companies who have gone

through such a program. An alternative is to engage, as an adviser, some qualified consultant who has participated in many such undertakings.

Clearly top management has not the time nor the specialized skill to understand and follow such a program in detail. The detail must be left to those who do have the time and the specialized skills. But top management must -

- a. Understand the need for doing it at all.
- b. Realize the size and character of the job to be done.
- c. Provide the budget, organization, personnel and stimuli needed.
- d. Arrange for coordination of the broad program.
- e. Set up to measure results and
- f. Regulate the program based on results achieved.

Dr. J. M. Juran has since 1924 been associated with quality control and other management problems, first as an industrial executive, then as a government official, and currently as an author, educator, and consultant to leading industrial companies. A member of the bar as well as a licensed professional engineer, he holds the Worcester Reed Warner Gold Medal of the American Society of Mechanical Engineers for "outstanding contributions to the control of quality in mass production". His books include "Management of inspection and Quality Control" (Harpers 1945), and "Handbook of Quality Control" (McGraw-Hill; in preparation).

** Professor and Chairman - Department of Administrative Engineering - New York University*

NOTES:

A SOUND PROGRAM FOR IMPROVING VENDOR'S QUALITY

By: Edward M. Schrock*

1. The Consumer's Responsibility. The first step to be taken in improving vendors' quality must be taken by the consumer. This step involves the development of:

1. Sound specifications. The consumer should be certain that the quality characteristics specified are really needed in order to further process the material or to satisfy the customer. Additional steps to be taken are:

2. Be sure the vendor is fully informed of your needs. This may be provided by:

a. Written instructions. The drawing should indicate the quality characteristics required and their relative importance (critical, major, or minor). The drawing may carry a list of tests and inspections to be performed or may refer to the consumer's specifications, copies of which should be supplied to the vendor. Contacts with the vendor should be arranged for through the Purchasing Department.

b. Visits to the vendor. Nothing will take the place of person to person contacts in working out quality problems. Such visits will provide the consumer with an opportunity to determine whether the vendor is properly equipped to supply his needs and to observe the kind of housekeeping the vendor maintains in his plant.

3. Suitable inspection and testing of incoming material. Attributes characteristics should be inspected according to recognized sampling tables such as the Army Ordnance Tables, Dodge - Romig Sampling Inspection Tables, or the Navy Tables. Suitable inspection record cards should be kept for each part from each vendor giving the date, size of shipment, number of pieces inspected, number of defectives found, disposition of the shipment, and nature of principal defects found.

Variables quality characteristics should be plotted on control charts which are printed on master sheets suitable for duplication of copies. Copies should be supplied to the vendor at periodic intervals or whenever unsatisfactory quality is received.

4. Rating of vendors. Once a month each vendor should be given a rating determined by the percentage of acceptable shipments received. If practicable, laboratory and inspection results should be plotted separately. Copies of

these charts should be made available to the vendor through the Purchasing Department.

5. Information Booklet for Vendors. This booklet should briefly outline the principal features of your quality control program and should acquaint your vendors with the forms and procedures you use. It should not be a text on modern quality control or sampling theory.

II. The Vendor's Responsibility. Quality must be built into the product by the vendor. To this end the vendor should:

1. Be properly equipped. He should not attempt to produce parts on obsolete, worn out, or inadequate equipment. His shop should be kept in good order and made as attractive as practicable.

2. Test and inspect his product. He should be equipped to perform all the tests and inspections the consumer will perform. He should sample lots prior to shipment and should institute such process controls as will help achieve good quality. He should aim to supply a somewhat better quality level than that specified by the consumer.

3. Certify to the consumer the results he obtains on his inspections and tests prior to shipment. This should be done on a suitable form developed by the consumer. Copies should be forwarded once or twice a week or as convenient according to the shipments. When the consumer finds over a substantial period of time, say six months or more, that his own test and inspection results closely parallel the vendor's certificates, he may go to spot checking. This is the ideal arrangement for then the bulk of the inspection and test effort will be performed at the most logical spot - where the material is made. Bad material will not be shipped. The vendor will learn sooner when he is in trouble on quality and consumer's expenses for inspection and testing will be reduced. In the end, everyone will benefit.

** Division Engineer - Refrigerator Quality Control Division
General Electric Company*

NOTES:

BUILDING SALES THROUGH QUALITY CONTROL

By: S. H. McKibben*

A variety of factors such as price, appearance and customer needs are instrumental in the initial sale of a product. Repeat sales depend primarily upon quality of the product. A product failing to give satisfactory service will not be purchased a second time.

Steps taken at Corning to assure the quality of its outgoing electrical products such as incandescent and fluorescent bulb blanks, radio tube envelopes and sign light tubing by developing a method of process control in place of individual piece inspection resulted in a practical solution from an economic point of view.

The company's problem was therefore one of developing a method of process control using automatic recording equipment and charts. Moreover, since the manufacture of these products was not only a high volume, but, a high speed operation, *radio tube envelopes and incandescent bulb blanks are automatically produced at the rate of several hundred a minute*, such controls could not be installed at the inspection end of the production line, but had to be placed at the machine end. This was the only way in which deviations from allowable limits could be detected before large quantities of unusable product were lost.

Corning's quality engineers, aided by research, development and manufacturing groups, studied various ways of improving overall quality levels and eliminated costly reinspection of borderline ware. The job faced by these men was far from simple, since it is much harder to improve quality which was already good, than to improve quality which might have been poor. The various phases of establishing the new controls was successfully accomplished, however, and resulting improvements proved of double benefit to customers. For not only was Corning able to supply better quality ware, held to closer tolerances, but they were able to do so at reduced prices or prices increased conservatively in view of rising material costs.

As a result, it was decided to negotiate Acceptance Sampling Plans with those of Corning's customers who were interested in learning what could be reasonably expected for the prices they were paying for the ware they purchased. Such plans would enable customers' Incoming Inspection Departments to report rejections to Corning in a manner which would give the maximum amount of information needed so that immediate correction might be made.

Acceptance Sampling Plans, now successfully operating on all types of Corning's electrical products, are proving of increasing benefit to both the company and its customers, who have already begun to substantially reduce incoming inspection of ware and in certain instances, eliminate such inspection entirely.

The writer cautions, however, that the success of Acceptance Sampling Plans hinges upon three factors:

1. The specifications controlling the quality of products must be thoroughly understood and mutually agreed to by both manufacturer and customer.
2. Inspection methods and tools in the plants of each must be identical.
3. The allowable percent defective in the manufacturer's plant must be lower than that covered by the plan.

Process control has proved invaluable as a method of maintaining and improving quality. The benefits derived have not been confined to Corning alone, but have been extended to customers in the form of better products and lower prices. The company believes that this improved quality has not only protected their markets, but has been instrumental in increasing sales through new business and repeat business.

* B.S. in *Electrical Engineering* - Virginia Military Institute
Supplementary courses at Carnegie Tech - Manager of Quality Control and Methods - Corning Glass Sales Engineer, Corning Glass Works

NOTES:

BUILDING A QUALITY-MINDED ORGANIZATION

By: R.F. Hurst*

In the 123 years of its existence, the Bigelow-Sanford Carpet Company has built up a national reputation for the quality of its products. This reputation has enabled us to build up a volume of business which has made our Company the world's largest producer of Woven carpet and rugs.

A PROBLEM IN QUALITY

During the war, we lost a good many of our people to the draft and to higher-paying jobs, in addition to normal turnover. Since the war, we have steadily expanded production to the point where our current operation is six times the volume of the fourth quarter of 1945. Today, even though we have 3141 people on our payroll with more than 10 years' experience in the making of carpet, we also have about 3800 people who have been with us less than two years.

After reconversion we first concentrated on expanding production, then on cost reduction, and then, as our rejects and imperfections increased to about double pre-war experience, quality became paramount. While defective carpet did not pass our inspectors and reach our customers, the imperfect goods that accumulated, causing nearly \$2,000,000 annual sales loss in discounts, emphasized the quality problem.

OBJECTIVES FOR A QUALITY PROGRAM

Since prices in our highly competitive industry differ little, grade for grade, among 40-odd manufacturers, we strive to give a "plus" with unequalled quality of materials and craftsmanship, as indicated by our slogan "Quality You Can Trust".

An analysis of our difficulties led to the establishment of definite objectives for our post-war Quality campaign. These were:

1. To make every employee aware of Bigelow's reputation for quality.
2. To make every employee conscious of the fact that his job security depended, to a great extent, on Bigelow's reputation for a quality product.
3. To make every employee realize that he was making a daily contribution, good or otherwise, to the quality of our product.

4. To improve the quality of workmanship in all departments, not only to decrease imperfects, but also - and more important - to increase our machine efficiencies by providing better materials at each successive operation.

5. To improve the relations of our Quality Control Department in its application of modern techniques.

FINANCING THE PROGRAM

Immediate quality improvement does not mean more inspectors, more rejects, lower productivity, etc.

Consider the potential savings from improving quality of workmanship throughout. Certainly, *less inspection* will be required and even *less supervision*. Add to those possible savings the cost of *reworks* and *scrap*, the benefits of an accumulative better product from operation to operation, the effects of a more uniform and better final product, and the tremendous *decrease in waste* through careful handling and storage. A surprising amount of potential savings will result to finance the program.

In our own case, we were able to set up an immediate 12-month goal of \$1,806,000 savings in operating costs through "quality improvements".

PLANNING THE PROGRAM

Members of our Sales, Sales Promotion, Community and Public Relations, Display, Employees' Service, and Training Departments helped us organize our program for the improvement of quality. As a result of a series of meetings, a plan of activity involving all departments and all employees and covering a period of 8 to 10 months was established.

A PROGRAM FOR QUALITY IMPROVEMENT

Personal letters were sent by our executives to all supervisors, a special Quality Improvement Suggestion Contest was set in motion among our Foremen, and a series of articles on quality appreciation began to appear in our employees' paper.

Employees' slogan contests were started and winning slogans were attractively displayed, as posters, around the mills.

A special weekend conference of all supervisors was called and a challenge for improvement of quality in every department was accepted.

A sound movie and special display of good and bad "workmanship"

were designed and arrangements were made to show each to every employee of the Company.

A special award was devised for special production and craftsmanship.

Plant Quality Control Committees were organized to *plan* quality improvement.

RESULTS OF QUALITY IMPROVEMENT PROGRAM

Such a program as outlined, reaching into every department and to all levels, cannot fail to create the indispensable appreciation for quality that underlies true "quality-mindedness".

Results are apparent already. Imperfects have decreased. All Supervisors are pushing quality and have submitted many suggestions for quality improvement. Productivity and efficiency are increasing. In addition, intangible benefits are accruing such as better esprit de corps, better line and staff relationships, revival of interest in preventative maintenance, and new job enthusiasm in the Quality Control Department.

Better quality *does* cost less - we can prove it.

- * Assistant to Vice President of Manufacturing
Bigelow Sanford Carpet Company

NOTES:

CONSUMER STANDARDS

By: Ephraim Freedman*

The subject of consumer standards embraces many facets which must be considered if favorable consumer reaction is to result.

Type of Standards.

The Agencies engaged in development.

The use and the evasion of such standards.

The problems involved in developing and safeguarding the standards.

The methods used for the control of quality.

Reaction of manufacturers to such methods are presented along with consumer economic problems and production cost consideration.

Another phase of the paper deals with the study of the complaint situation in terms of customer reaction on the store level.

Another, with manufacturer attitude.

The quality control inspection on the incoming level is also described with emphasis on modifications necessary to make it effective at minimum cost.

Finally, those particular segments of industry which appear to have more than the normal number of quality problems are pinpointed for the purpose of seeing where there exists the greatest need for quality control.

* - Director - Macy's Bureau of Standards, Chemist - Professional Engineer, Past President - American Association of Textile Technologists, Past Chairman - N.Y. Chapter American Association of Textile Chemists and Colorists Director - Textile Research Institute, Fellow - American Institute of Chemists, Dean - Advisory Board Bedding Div. New York State Department of Labor, American Chemical Society, American Society for Testing Materials

NOTES:

CAN MANAGEMENT NOT AFFORD STATISTICAL QUALITY CONTROL

By: Prof. W. A. MacCrehan Jr.,

To make a decision to sponsor a Statistical Quality Control function, management must understand the application of the function but not its operational details.

Management must weigh three factors:

1. The technique must perform a "Trouble-Shooting" service to overcome manufacturing difficulties.
2. The technique must improve consumer-manufacturer relations.
3. The technique must save dollars proportionately to dollars expended.

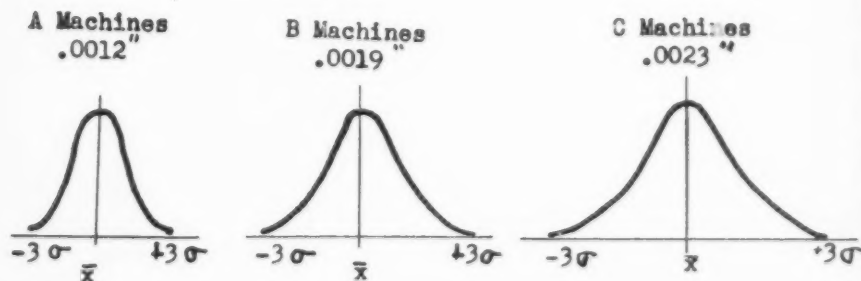
In considering whether management can afford to ignore Statistical Quality Control, let us look at three case histories in three separate fields of manufacture.

CASE #1

A Connecticut firm has a contract to manufacture motor shafts. After a month's manufacture, the results are:

- a. Not meeting production schedules.
- b. Rework labor costs eating up estimated margin.
- c. Scrap excessive.

A statistical analysis was made of the three lathes employed. The following are their normal variations:



Shaft requirements are:

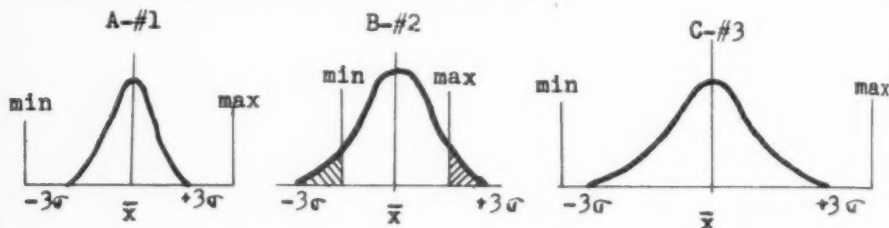
Shaft #1
1.125 \pm .001
-.001

Shaft #2
1.500 \pm .000
-.001

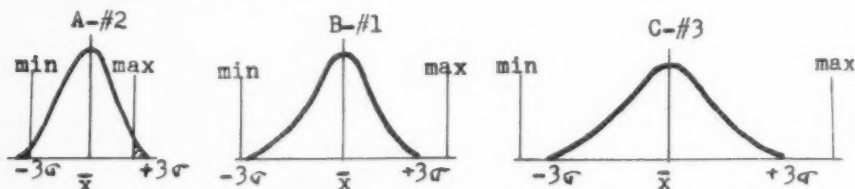
Shaft #3
1.875 \pm .000
-.003



Current Assignment of shafts to Machines:



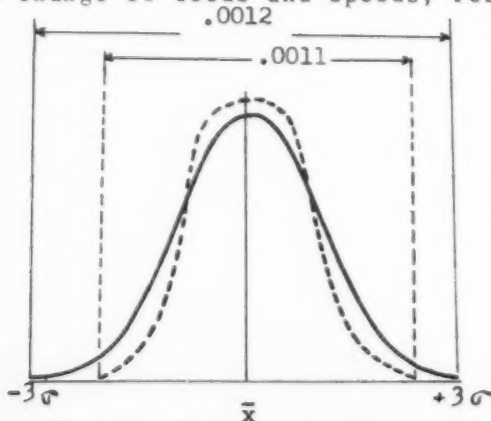
Reassignment was made:



This provided some drift on shafts 1 and 3 and help for shaft 2. Shaft 2 still in trouble.

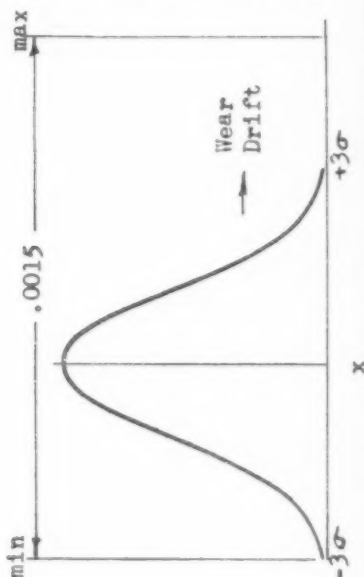
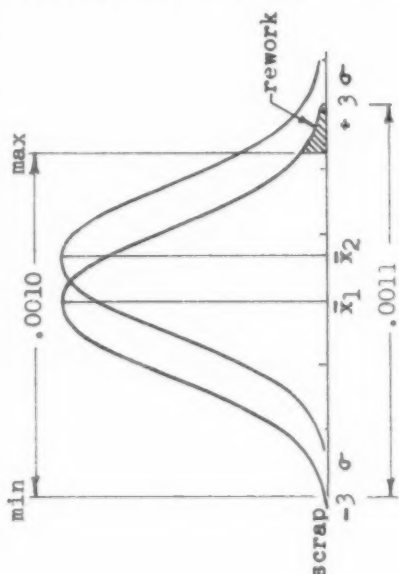
The capability of machine A being greater than requirements for shaft 2, steps were taken to improve the performance.

Retooling, change of feeds and speeds, resulted in:



which still did not eliminate loss.

The customer was sent a statement of findings. .0005" additional was allowed, solving the problem for shaft 2.

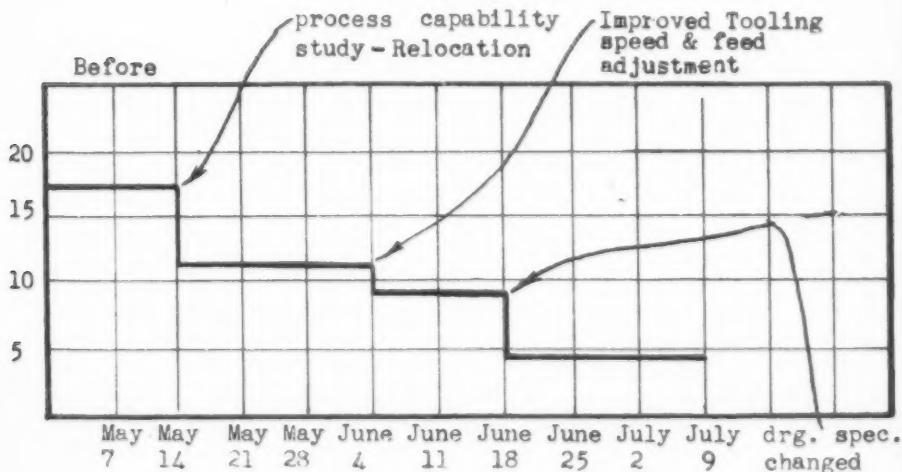


Savings due to this study showed:

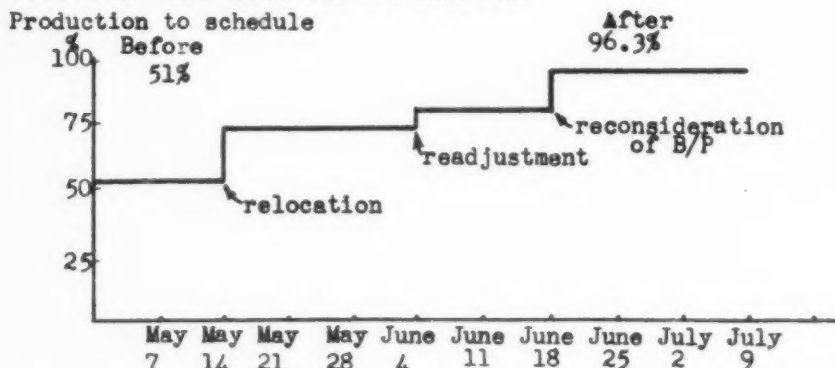
\bar{x}_1 = setup at start

\bar{x}_2 = location after wear drift

	Before	After
Rework	17%	1%
Scrap	11%	0.5%
Rework	8.5%	
Rework	4.0%	



Production was affected as follows:



CASE #2

A Brooklyn paint manufacturer maintained a research laboratory to investigate new methods. Test specimens were given a life test under salt spray.

Research developed a new vehicle that appeared promising and the following data was observed: (units in years)

Test A	6.7;	7.1;	7.1;	6.5;	6.9;	6.3;	6.8;
	6.1;	6.4;	6.3;	6.7;	6.4;	6.2;	6.4

Average life for this and other tests:

Test A	6.56
B	6.41
C	6.39
D	6.40

The current process has averaged 6.3 with a standard deviation of .11 years

The plant Statistical Quality Control man was brought in prior to a decision. He set up a "t" test and found no significant change.

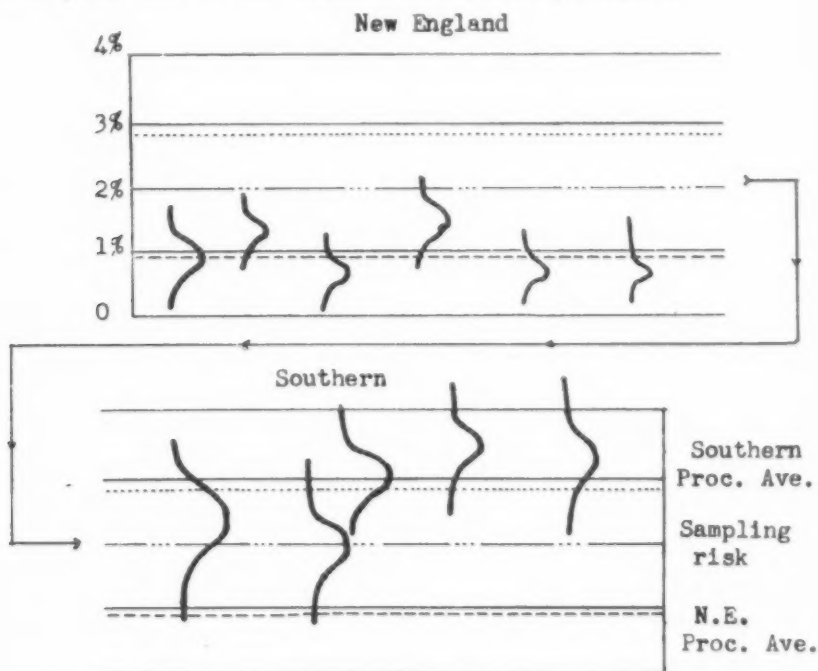
Management couldn't calculate dollars saved by disallowing plant changeover for no gain in product. However, it is good management to know, where research is involved, whether or not progress is at hand.

CASE #3

A Mid-Western firm did business for years with a New England supplier. Price competition from a new Southern source brought the contract to a close.

Knowing his product to have an Outgoing Quality Level of less than 1% defective, the New Englander proposed to his former customer a Double Sampling plan of incoming inspection set at 2% defective risk based on a 1% process average.

The plan was tried with the following result:



The Mid-Westerner concluded that the price differential was offset by lack of quota deliveries due to rejected lots.

To summarize the case of management consideration of Statistical Control of Quality: The technique has the facility of yielding impartial facts from controversial problems, and ringing the bell that sounds the call - "Management cannot afford to overlook the technique of Statistical Quality Control."

* Professor - New York University

NOTES:

DIMENSIONS AND TOLERANCES - THE FOUNDATION OF QUALITY CONTROL

By: Earle Buckingham*

The determination of the size and the variation in size of any feature of a product alone, whether by conventional inspection methods or by means of statistical control, means nothing. If that part or feature of a part has a definite duty to perform, then its size must be such that its full duty will be adequately performed. The term QUALITY by itself and in the sense used in QUALITY CONTROL is meaningless. A product is not simply good, it must be good for a certain use, and the term QUALITY apart from the use in view means nothing. Good Quality means good for a certain use.

The dimensional condition necessary to meet this QUALITY may, at times, need to be determined by trial or be established from actual experience. Once it is determined, or even assumed for the purpose of making some definite start, it must be specified in unmistakeable and definite terms. It must be so specified that any one "skilled in the art" can, by means of definite measurement or comparison, demonstrate definitely that either it does meet the specifications or it does not meet them. There must be no foggy region of uncertainty. Whether or not the dimensional specifications are the correct ones, there must be no uncertainty about the actual dimensional conditions that are specified. If these specifications themselves are incorrect, they can be corrected. If the method or language used to specify them is ambiguous and indefinite, then no correction is possible until the language has been perfected.

The present language of drawings as it affects the dimensions and tolerances is incomplete, ambiguous in many respects, and dumb in regard to many very important dimensional conditions. Whether words or symbols are used, a precise language with precise definitions is the first requirement of a clear and definite specification.

It must be recognized that many different kinds of dimensional information are needed on the drawings. In this respect, the dimensions may be classified into the following types:

- a. Limiting dimensions or dimensions and tolerances which must be rigorously maintained.
- b. Constructional dimensions which may be seldom, if ever, measured directly in production.
- c. Calculated dimensions which may represent some basic starting point but which are never measured directly in production.

Some notation should be adopted to identify these different types of dimensions.

The limiting dimensions themselves serve different purposes and must be considered under different categories. Effective methods for their control require different treatments. But first of all, it is necessary to reach a definite agreement as to the fundamental meaning of the limiting dimensions on the drawing. For this, in the writer's opinion after over forty years' contact with this problem, the only logical and defensible interpretation is that the limiting dimensions, on the part drawing represent the requirements of the inspection gages. In other words, it must be possible to translate every limiting dimension into a definite form of measurement or definite design and size of an inspection gage. Hence these dimensions specify specific tests with specific gages and all parts of the product that meet these tests must be adequate dimensionally to meet the service or use requirement. This is no easy task.

Limiting dimensions are required to specify the following conditions; (a) conditions of size; (b) conditions of form; (c) conditions of operation or functioning. The method of specifying the permissible variation or tolerance must be different on each of these conditions. Conditions of form or conditions of position treated in the same manner as conditions of size lead to chaos. Gages of size, gages of form, gages of position, and functional gages all have quite different characteristics. The present practice takes care of but little more than conditions of size, with a slight approach to conditions of form. Conditions of position have been ignored almost completely. It is the purpose of this paper to present one possible method which represents a start, at least, for a vocabulary and dictionary which will cover all of the different dimensional conditions.

* *Professor - Mechanical Engineering
Massachusetts Institute of Technology*

NOTES:

GAGE STANDARDIZATION ROOMS

By: C. H. Borneman*

Most Gage Manufacturers maintain the temperature of their gage inspection rooms to the International Standard requirement of 68° F. (20° C.). The reason for this is that all materials expands with a rise in temperature and contracts when the temperature decreases. For example, a pin gage 24 inches in length increases 1/1000 of an inch when subjected to a rise of 6½ degrees. If this same gage were measured at any other part of the world under the same conditions the results would be identical.

One important requirement of an efficient gage room set up is ample supply of good clean air with the humidity maintained between 57 to 59%. This requirement is necessary for the proper functioning and life of the gage equipment as well as for the comfort of the gage room personnel.

Clean air is usually entered through ducts located in the ceiling at the center of the room at a velocity which distributes evenly without drafts, and returns through ducts with adjustable registers located in the base board back to the filtering system.

For best operating efficiency of the temperature control equipment, the room should be completely insulated including the ceiling. Outside walls should be voided.

Fluorescent lighting is the best type of illumination for such rooms. Heat transfer from the lights should be kept to a minimum. If daylighting is resorted to, it should be from the North.

Battleship linoleum of a light tan is usually used as floor and bench covering. The room must be kept scrupulously clean at all times.

To prevent sudden temperature changes, the entrances are protected by vestibules and where possible service is rendered through windows.

The main object of this type of room is to maintain the air at a constant temperature. Large masses of metal such as surface plates assist in maintaining this temperature of the gages, if they are allowed to remain long enough in the room to become saturated. Some Gage Manufacturers go so far as to keep the gages to be measured in a bath of Toluol and all possible precaution is taken against heat transfer from the hands or body.

- * Supervisor Tool & Gage Service - General Electric Co.,
Schenectady Works, Schenectady, New York

NOTES:

REDUCING MANUFACTURING COSTS BY STREAMLINING DISTRIBUTION OF QUALITY INFORMATION THROUGHOUT THE PLANT

By: George A. Fort*

Paper forms cost money! The forms themselves may cost very little more than the paper in them, but the cost of filling them out and analyzing the data, particularly if it is of little or no value, can become very expensive.

Manufacturing facilities are usually overburdened with extraneous paper work because there is a common tendency to prepare unnecessary forms without justifiable reason.

Our Final Inspection Department had six different forms which were used to process material through the Department. A thorough study was made and as a result, one form was developed to replace the six old ones. This led to all forms being placed under suspicion, and they are now in the process of being studied carefully for overlapping and general usefulness. As a result of our efforts so far, we have not only reduced the cost in our own department, but also in several others. Since the Quality Control Department deals with a lot of forms, it behooves you to analyze your paper flow and determine if the expense is warranted.

Before you can improve on a procedure of paper flow, you must know the details of the procedure being used at the present time. Securing this information necessitates someone out in the plant following the procedure through step by step. Experience has taught us that the arm chair versions of a procedure obtained around a conference table differs from what actually happens. Our technique forces you to get out in the plant and get all the facts. The information obtained is written up in chronological sequence and is used simultaneously with a "Flow of Information" diagram that is drawn up on the procedure. By using a systematic means of reviewing the "Flow of Information" diagram, the weaknesses of the present procedure are easily determined.

Actually there are two kinds of forms, Decision Documents and Information Documents. The Decision Document is a directive, someone is deciding what is to be done. The Information Document tells us if it was done. The success of any program depends upon the decisions that are made and the assurance that they are carried out. It is quite obvious that when you are reviewing the paper flow procedure of your organization, it is imperative that you know who is making the decisions, and when they are being made. Therefore, you must have a ways and means of showing the paper flow in such

a form so that you can see the entire picture and thereby make an intelligent and constructive analysis. That is exactly what our "Flow of Information" diagram pictorially reveals.

Our technique simplifies finding the source of evils, it expedites the flow of materials, it reduces process cost, and it is a permanent record which can always be referred to at a future date. When you devise your paper flow procedure, it is written up along with a new "Flow of Information" diagram. These offer excellent tools for educating the personnel involved.

* *B.S. in Mechanical Engineering - Case Institute of Technology*
Quality Control Engineer - Parker Appliance Company,
Cleveland, Ohio

THE QUALITY CONTROL DEPARTMENT, AS A TRAINING GROUND FOR SUPERVISORY PERSONNEL

By: E. H. Robinson*

Promotions from Quality Control into supervisory management positions are made only infrequently in industry not because capable quality control men are not available, but because industrial management in general does not yet appreciate the value of the Quality Control Department as a source of such personnel.

Actually, it can be easily argued that there is no department in an organization which gives a man as broad a perspective or as excellent an opportunity to study the relationships between organizational functions as does the Quality Control Department. Its work of necessity requires constant consideration of all activities and gives its people a rounded training, the ability to analyze all factors, and a tolerance of the other man's viewpoint.

Naturally, such promotions temporarily weaken the quality control function, since invariably a top-ranking individual is the one selected. However, the incentive which it gives to other personnel in the Quality Control group and the seed which it plants in the manufacturing operation will repay the department for the "loss." At the very least, Quality Control is gaining a friend and a champion in the manufacturing group, because obviously the promoted man has during his period of training become imbued with the quality perspective.

The Quality Control department is not in a position, however, to be an efficient training ground unless it is recognized as a vital part of the organization. If it is regarded merely as overhead which must be tolerated for prestige or advertising purposes, it is doomed to failure. Even if the attitude of top management toward it is one of passive acceptance of its presence, it is doomed to failure.

The quality control organization, to achieve its full purpose, must have the active and militant support of the man to whom it is responsible. It should be so close to top management that no decision having a possible effect on product quality would be made without it. Its opinion should be sought when the manufacture of a new item is contemplated, and if some ingredient or characteristic of the product is to be changed.

If the attitude at the top toward quality control reflects this confidence, and if the opinions and decisions of this group are firmly defended or at least sought and weighed

against other opinions, the quality control organization will make worthwhile contributions not only to the quality of products and to its cost reduction, but to the pool of trained, capable men available for supervisory positions in both production and administration. We have two outstanding examples on our own panel, with Mr. Thompson as a Works Manager and Mr. Reinhardt as a Manager of Employment and Training.

It is important, of course, in any training program that the men brought into the quality control group have adequate potentialities. This is done at Johnson & Johnson by giving prospective inspectors and group leaders a series of tests in our Personnel Department.

The Humm-Wadsworth Temperament Test will indicate to us whether an applicant has an integrated personality and can readily adapt himself to people and varying conditions. The Wonderlic and Otis Tests will tell us his intelligence level.

It is amazing how many educated people are poor in arithmetic; we eliminate this handicap by giving applicants the Schorling-Clark-Potter Arithmetic test. Eyes are checked for visual acuity, astigmatism, and color blindness by the Keystone Telebinocular Test. Sharpness in picking up visual defects is shown by the results of the Minnesota Clerical Test.

If the man passes all these, in addition to the interview and physical examination, we feel that he has the potential at least to develop into a supervisor. Apparently our management feels the same way, for this program has over a period of fifteen years developed two superintendents, two assistant superintendents, two foremen, and a number of other important production men.

* *Director of Quality Control - Johnson & Johnson*

NOTES:

QUALITY CONTROL AS A TRAINING GROUND FOR FUTURE SUPERVISORY PERSONNEL

By: E. F. Gibian*

1. The Three "M's"

Supervision deals with men, materials, and machines, and these three elements do not follow rigid rules. It has been recognized for sometime that our supervisors who run our factories need some fundamental training to understand the functions and capabilities of the three elements with which they deal. We have been teaching them psychology and other social sciences to deal with men; some chemistry and metallurgy to deal with materials; and some mechanics and other applied engineering sciences to deal with machines. But until recently, we have failed to recognize the basic importance of the interrelation of these three elements, which is governed and influenced by chance variations inherent to them. To properly train supervision, we must make them understand the fundamentals of probability and statistics, and we must teach them how to apply this knowledge to their everyday tasks.

2. Need for Training

There is a need for a textbook on Statistical Quality Control---a better term may be Statistical Process Control--whose specific aim should be to serve as a medium for the training of supervision. Until such a textbook becomes available, Management must see to it that its Quality Control Engineers devise their own training courses for such a purpose. Courses of this nature have already been conducted by many concerns; some met with success and some with failure. Those which failed too often adopted the slogan, "Let's make it practical and forget about theory". This is a mistake. There is no royal road to statistics and Statistical Quality Control.

3. Objective of Training

We at Thompson Products have consciously used Statistical Quality Control as a training ground for supervisory personnel. It is a part of our continuous supervisory training program, in which we attempt to equip our supervisors with a rounded-out knowledge of all tools of Management. We find that Statistical Quality Control serves two distinctly useful purposes. One, it acquaints all supervisors with the various techniques of Statistical Quality Control and it gives them an understanding of statistical concepts of Quality Control procedures. Two, it is an excellent medium for developing

the faculty to think logically and to analyze critically all factors influencing a given situation and a given set of data. The course has for its aim not so much the training in the use of Quality Control procedures, but rather teaches the supervision to understand when a situation calls for statistical analysis, so that they can call for help from Quality Control specialists available in their divisions.

4. Methods of Training

The training in Quality Control should not shun theory, but it must be presented in an entertaining manner. Explain, for instance, the probability concept and the formula for the binominal distribution, in order to show the logical basis, on which the theory is built, but you need not expect or demand the "students" to master the mathematics involved. Be sure that you have simple and entertaining illustrations taken from everyday life or work ready for them to show how the theory is applied. Use cases from your own shop to illustrate wrong decisions made in the past, because the proper understanding of Statistical Quality Control principles was not known, and contrast this with situations where a statistical approach rendered a correct and sometimes startling solution. Show how the supervisor can better train his operators with the help of Statistical Quality Control procedures.

5. Example of Training Results

A startling example of successful supervisory training in Statistical Quality Control occurred in one of our divisions, in the manufacturing of a rather complicated, high precision aircraft engine subassembly. The condition of the machining equipment was blamed for the inability to maintain the required close tolerances and a machine overhauling program, involving an expense of \$25,000.00, was contemplated as a remedy for this situation. The Quality Control trained foreman recognized the necessity for a sound basis of such an action and called in the Quality Control Engineer for a thorough analysis. This analysis, undertaken by the foreman and the Quality Control Engineer, showed that the inability to hold required tolerances was due to the operators, not to the machines. Control charts were set up for each machine and the products are now held even within closer tolerances than the specifications required. \$25,000.00 alone was saved by avoiding the unnecessary machine rehabilitation program, not to speak of the obvious other savings associated with this statistical approach requested by an alert foreman.

Correct Quality Control training of supervisory personnel pays off.

* - Chief Industrial Engineer, Thompson Products, Inc.,
2355 Euclid Avenue, Cleveland 17, Ohio

NOTES:

THE QUALITY CONTROL DEPARTMENT AS A TRAINING GROUND FOR SUPERVISORY PERSONNEL

By: Harris Reinhardt*

One of my responsibilities in Sylvania Electric is to operate a central employment service. This activity is called upon to fill openings for organization and technical personnel throughout the entire Company.

Whenever a requisition is received at our central employment department our first task is to survey the possibility of filling the job by promoting someone within our own organization. This means that we are constantly combing and re-combing our entire organization looking for men who can be advance into positions of many different types.

Having once been in quality control work myself, I am perhaps a little prejudiced regarding the value of this type of training, but as I survey the situation from an overall company viewpoint, I find that we have men in almost every important phase of our operation who, at one time or another have been associated with quality control activities.

Our feelings in this matter are reflected by the following quotation from the booklet we have prepared for college students, describing opportunities for training in our company,

"Quality control work provides excellent training in plant operation, as it requires familiarity with all phases of the production process, as well as the ability to work out practical inspection and sampling procedures, and the training and supervising of inspection groups".

It has been our experience that a man who had made a success in a quality control activity has many of the qualifications necessary for other types of work. In other words, it is our feeling that quality control in its broad aspects tends to give a man the proper background for these broader functions.

When I speak of Quality Control in its broad sense, I certainly do not mean inspection alone. I do mean, however, that broad coordination of the many functions which are required for successful manufacturing including Purchasing, Engineering, Manufacturing, Personnel, Industrial Engineering, Inspection, Safety Engineering, and Sales. A good Quality Control man is one who is able to work successfully with each one of these functions, for each one certainly plays an important part in the economical manufacture and dis-

tribution of products of good quality.

Upon looking back at it then, it does seem to us that these good Quality Control men have acquired through their activity a broad perspective of many phases of manufacturing and when they are inherently capable men, they are naturally qualified for managerial and other fundamental positions in the manufacturing enterprise.

* *Manager Employment & Training - Industrial Relations Department, Sylvania Electric Products Inc.,*

NOTES:

QUALITY CONTROL AS A TRAINING GROUND FOR SUPERVISORY PERSONNEL

By: E. D. Thompson*

The broader aspects of quality control offer an excellent, somewhat unique and possibly exclusive training ground for all supervisory personnel. This training need not be limited to manufacturing, service, or engineering department, any more than training in inventory control, budget control, production control, and so forth, should be limited only to those departments or executives who are directly affected. In business today it is more essential than ever that all departments be so integrated that they operate effectively as a single unit and at least a fundamental understanding of each department's activities be understood by the entire business organization. This is especially true of the quality control division - for a major purpose of quality control is to establish a quality level that will be acceptable to the consumer, and yet permit an article to be manufactured and sold at a profit. It is easily understood that it is entirely possible to manufacture a product of such high quality that it is impossible to market it at a price that would yield a profit and, on the other hand, a product of such poor quality that it would not give the service expected and would probably be impossible to market at any price. Who would be affected by these factors then - the manufacturing department surely, as their production, tooling, planning would all be affected by the factors of quality demanded; the sales department as their potential sales would be affected by the quality, or lack of it, and the price which the consumer would be required to pay; the accounting department, surely, for the spread between manufacturing cost and sales price must necessarily be great enough to take care of operating expenses and in addition show a profit.

So far we have approached the subject of quality control as a training ground for supervisory personnel only from the standpoint of gaining a fundamental knowledge of the necessity of establishing a satisfactory quality level. Let us review the method by which quality control operates and it is apparent that the supervisory personnel must have some knowledge of the charts employed, the data used, and the type of reports required to be able to interpret this information into action - to be constantly on the alert to eliminate the causes of scrap that would cause the quality to drop below the desired level, or cause manufacturing or handling operations to be too costly and naturally increase the manufacturing burden and, in consequence, reduce the profit. It is not sufficient to know how to construct charts and interpret them; the quality control department must be able to convert

this information into reports that are simple, quickly available and authentic. It is important that quality control reports be placed in the hands of the supervisory personnel as it is for this purpose that we have a quality control department.

It follows then that the supervisory personnel have some knowledge of quality control methods as it will be difficult to understand the information available and, too, supervisors are prone to be somewhat suspicious of information when they do not understand the methods employed in collecting the data. Possibly the biggest problem of establishing a quality control department has been the resistance of supervisors and top management to a system of controls that they did not understand. The successful installation of quality control in almost every company has nearly always been preceded by some training of all supervisory personnel. There are a number of sad experiences in quality control where all of the training has been limited only to those people actually engaged in quality control work itself.

Last, but by no means least, is the stimulation of thinking aroused by training in quality control work. Every day we hear of new methods where quality control techniques have been applied to market research, sales problems, selection of personnel for various purposes in both manufacturing and other divisions -- truly, quality control by no means describes the almost limitless uses that can be found for this industrial tool.

* Works Manager - Badger Meter Company

NOTES:

ROUND TABLE ON EDUCATIONAL METHODS IN QUALITY CONTROL

By: Loyd A. Knowler*

Without an adequate educational program, formal or informal, there is little, if any, need to consider the application of statistical quality control to the production of a product or of a service. A similar statement can be made about other worthwhile projects. Variation is one of the basic principles of these modern scientific methods as applied to design, specifications, production and inspection, or to consumer demands. So is the realization that various procedures are helpful to assist in the attainment of the objectives. For these reasons the Planning Committee of this Third Annual Convention has invited these representatives of industries, publications, and schools to discuss the various aspects of an educational program so that we might have material available to draw upon so as to correlate the suggestions needed in our own plants. In so doing, each participant recognizes that statistical quality control helps to lower costs: that CONTROLLED QUALITY is GOOD ECONOMY.

* Chairman - Department of Mathematics and Astronomy
State University of Iowa
Iowa City, Iowa

NOTES:

TRAINING -- A CHALLENGE TO EACH SECTION

By: Arthur Bender Jr. *

Our Constitution states that the purpose of the society is, "to create promote and stimulate interest in the advancement and diffusion of knowledge of the sciency of Quality Control and of its application to industrial processes".

There are several ways inwhich an individual can now acquire training in Quality Control methods. Some of which are:

1. By association with an individual with more Quality Control knowledge.
2. By taking an "In Plant" training course.
3. Through home study, using A.S.Q.C. Publications and the various test books now available.
4. Through University sponsored intensive ten-day courses.
5. By taking University Extension programs.
6. Through Section sponsored training programs

Some sections are now furnishing training in the following manner:

1. By stimulating interest in University Extension programs to be taught locally.
2. By organizing their own training programs. These courses may be taught by members of the section or by guest speakers.

Several types of courses are now being taught by sections throughout the country.

1. Very Elementary) These two correspond to the ten-day
2. Intermediate) intensive course.
3. What's your problem?
4. Advanced.

The needs of each group must be considered in planning which course or courses should be offered. The demand will probably necessitate giving the elementary course every year, whereas, the others may be alternated.

Serious consideration should be given to the time at which these courses are given. If the section serves a large area it is perhaps best to have the training program in the afternoon preceding the regular evening meeting. However, a larger number of people from each industry in a smaller area will be able to receive instruction if the classes are at night.

A section sponsored elementary training program should be developed with an entirely different approach than the intensive training course. This elementary course must cover the field in generalities without becoming too involved in technical details. It is important that the curiosity, imagination, and interest of the student be maintained throughout this critical period while his basis thinking is undergoing a change. In all respects, these courses should parallel the ones used for "In-Plant" training. The only difference being that in this case the people are from many industries.

The elementary course must include many visual aids and should furnish all the simplifications possible in the way of work sheets and calculating aids. If at all possible, this course should be taught *without* the use of symbols, formulas, or too much statistical terminology. It has been demonstrated that this can be done effectively.

Some time or other, each section faces the problem of providing program material to satisfy both the new and old members. Any compromise on this is unfair to either group and a training program for each level offers an excellent solution to the problem.

During 1946-47, *the third year of our section*, the attendance was falling rapidly because many of the original members had been transferred to other jobs and our programs were too complicated for the newcomers.

The next year as a result of training programs our membership more than doubled. This year we have had a further increase, so that in two years we have tripled our membership. The Executive Secretary's report of February 9, 1949 shows that we now have the fifth largest section in the country.

In conclusion, I would like to emphasize the benefits that may be derived from section sponsored training programs.

1. The individual benefits from the training received.
2. Industry benefits by having more trained people and by having a better understanding of each others problems.

3. The local section benefits by increased membership. *It is my personal opinion that anyone receiving training from a section should be a member of A.S.Q.C.*

4. A.S.Q.C. benefits by having a larger and stronger society.

From these benefits it is evident that section sponsored training programs serve in fulfilling the purpose of A.S.Q.C.

** E.E. - Purdue University, General Motors - Student Engineer, Design Engineer, Project Engineer, Quality Engineer, Past President Indiana Section for Quality Control 1946 Director A.S.Q.C., 1947*

NOTES:

ROUND TABLE ON EDUCATIONAL METHODS

UNDERGRADUATE INSTRUCTIONS

By: I. W. Burr*

Instruction in statistical methods for undergraduate engineers can and should be in the curriculum in two ways. First there should be one or more courses in the subject, and secondly, statistical methods should enter the subject matter and teaching of any course in which the student will be concerned with data significantly affected by random variation.

The statistical courses are perhaps most logically given in the mathematics department, but could be given wherever there is adequate instruction available. A first course would include averages, variability, frequency tabulation, normal curve, control charts and acceptance sampling, and as many of the following topics as can be taken: correlation, curve-fitting, multiple correlation, probability, significance of differences, analysis of variance, sequential analysis, theory of runs, statistics of combinations, chi-square, etc. Applications should be emphasized, with effort to help the student learn how to find an appropriate statistical tool to do the job at hand, and to know what are its basic requirements for sound application. The second and subsequent courses would include the topics above or others and round out the theoretical aspects.

The second main use of statistical methods in other courses involves a tremendous amount of salesmanship and instruction, and is a twenty (or more) year pull.

There are two more problems immediately faced in improving instruction. Selling the administration and other staff members and students on the value of statistical methods for engineers. This is a rather personal problem, but one in which the job done by every member of the Society helps a little bit. The second problem is that of finding good instructors, because, if a mathematician, he must have a sound industrial engineering outlook, and, if an engineer, he ought to be conversant with much of statistical theory. Such people are rare.

* - B.S. - Antioch College, M.S. - University of Chicago, Ph.D. - University of Michigan, Associate Professor of Mathematics Purdue University, Fellow American Society Quality Control

OUTSIDE HELP WITH IN-PLANT TRAINING

By: Ralph E. Wareham*

One of the problems faced by plant management in starting use of statistical quality control techniques relates to securing proper training for the personnel assigned to this work. It is frequently desired that men from a number of departments and staff positions become familiar with the methods of statistical quality control.

Unless college courses are given in the area where the plant is located, management is faced with the necessity of sending the men to an intensive quality control training course at a distant point. In reaching the latter decision it is frequently necessary to reduce substantially the number of men assigned to attend the course. This--in a sense--defeats the ideal plan originally contemplated.

An alternative solution is to provide in-plant training in statistical quality control by bringing in an outside consultant to the plant. Such outside help can present the principles of statistical quality control for the plant personnel assigned to the work. The consultant can also explain the principles to management, foremen, engineers, inspectors and other groups.

It has been found that teaching the principles of statistical quality control in the light of plant applications provides training of maximum value. Case studies can be discussed from the viewpoint of their practical importance and with the knowledge that such information is retained within a closed group of the company's own employees. This has the effect of developing teamwork in the entire quality control program.

Education is the key to successful application of statistical quality control and such education needs to be as practical as possible. In-plant training courses fit well into this objective

* President - American Society for Quality Control

NOTES:

DESIGNING THE IN-PLANT TRAINING PROGRAM

By: Wade R. Weaver*

Design of the in-plant training program, must, of necessity, be predicated upon the extent of intended activity in the application of Statistical Quality Control techniques. A start must be made somewhere, and it has been rather common practice to pick out a specific operation, or at most a department, select suitable personnel, and commence training. Particularly has this procedure been applied to inspection operations, around which many of the Quality Control installations have centered.

A much more sound procedure is to recognize the wide adaptability of Quality Control techniques to ALL phases of the entire operation and assume that sooner or later all operations and departments will become acquainted with it to varying degrees. If this hypothesis is assumed, and if we are to take full advantage of the scope of Quality Control it is not only sound but inevitable, considerable thought to planning the campaign is imperative. The following three-point, or progressive step program is recommended.

The understanding, backing and assistance of the management is extremely helpful, if indeed not essential. This includes not only the president or general manager but all major division or department heads such as engineering, tool design, metallurgical, purchasing, sales, maintenance, production, inspection, etc. They should receive at least eight hours of carefully planned indoctrination, including some major basic principles; they should be shown not how to use it but how it works, what it will do, the types of problems it helps solve, how it saves time and sharpens up judgement, promotes better customer-vendor relations and is a general all around management tool.

Next should come a similar presentation, but on a distinctly different plane, to all general supervision such as departmental and general foremen, key foremen and similar personnel. This should stress employee relationship, simplification of the job, decreased problems, smoother production and the simplicity of using such techniques under qualified direction.

The third step should consist of the selection of a particular problem or operation and the specific technique applicable to it, with detailed instruction of the involved foreman and individuals, such as operators, in the workings and application of only that individual technique to that specific condition. In this way confusion is avoided, confidence is gained and cooperation results.

The usual cardinal principles of teaching or instruction must apply in all three cases, but in addition, the hazard of presenting a highly technical subject must be understood. Careful analysis should be made of the three levels, the training experience, personal characteristics and reaction tendencies of the individuals involved. Direct appeal should be made to specific individuals; use of new technical terms should be avoided at all costs. Typical examples with which they are involved every day should be profuse but carefully selected. And finally, it should be remembered that if you are not smart enough to be able to explain every major point in five different ways without your listeners realizing you are doing so, you probably have failed to put across your point.

Following such a plan informs all key men in the organization of the aims and concepts of the program as well as how it is proposed to execute it. When actual installations commence there is no mystery; misunderstanding or suspicion; success is practically assured.

* - Metallurgical Engineer - Republic Steel Corp.,

STATISTICAL QUALITY CONTROL \pm TECHNICAL PUBLICATIONS

By: Mason E. Wescott*

The basic axiom for this discussion may be stated as follows: Statistical quality control is a scientific, engineering, professional activity. It brings to bear on the quality problems of industry the sharp tools of statistical reasoning and techniques.

Two conditions must be met to make use of these techniques effective: (1) they must be understood and accepted by those who propose to use them, and (2) they must be used in conjunction with practical experience and administered with imagination, tact, and patient persistence. It has been said that statistical quality control is 90% engineering and 10% statistics. Even if we accept this very debatable percentage breakdown, the fact still remains that 10% of this science depends on a fundamental core of technical knowledge in applied statistics.

Statistical quality control *without* technical publications is inconceivable. An appropriate literature to help carry and advance the science is indispensable. We learn much by word of mouth, but persons bitten by the quality control bug have an insatiable appetite for literature dealing with the *techniques* of the science -- convincing testimony that statistical quality control needs the support of good technical publications.

How many technical publications contribute to nurturing growth in the knowledge and practice of statistical quality control? The answer is (1) by providing a literature that will serve to improve and extend knowledge of basic theory, and (2) by providing a literature that will make basic theory operationally meaningful in terms of practical application. In short, technical publications serving the the quality control field must have two faces: creative theory and intelligible interpretation.

Does statistical quality control have the support of adequate technical publications? Not at the present time, but the situation will improve as wider acceptance of this science by industry takes place. The literature is strong on theory but weak on application. Most books thus far published in this field attempt to serve both needs, with varying shades of emphasis and success. No one will ever write the *perfect* book, but more and more books will appear as time goes on, and it can be expected that as experience ripens and exposure broadens these books will tend toward a really useful coverage of both theory and application.

Except for our own journal, *Industrial Quality Control*, coverage in the field of periodical publications is either concentrated on the side of pure theory, such as the *Annals of Mathematical Statistics*, or widely scattered in sporadic papers in other professional and trade journals. Frequently these papers are either trivial in content or missionary in purpose. *Industrial Quality Control* is the logical focal point for periodical technical papers in statistical quality control. The editorial policy of this journal accepts papers dealing with theory only when this theory is tied in with intelligible application. Even so, this magazine needs more good papers on the applied side, and a regular bibliography department to direct its readers to quality control papers available elsewhere in the literature.

How much of the technical literature should the quality control engineer try to absorb? Already it has grown past the point where any one man can digest all of it. The keynote is *growth*: let us, as members of the quality control profession, seek, read, and *study*, not just the things we already know about, but books and papers that stimulate our thinking, open up new possibilities, and strengthen our grasp of the fundamentals of our science.

Finally, who is to write the material that makes up the technical literature of statistical quality control? We shall probably have to leave fundamental work in creative theory to the academic and theoretical statisticians. When they deal with theory that *has* practical value, we shall have to look to men in our own Society to take this theory and make it intelligible and operative for the rank and file of quality control men. It is the responsibility of those of us who have the ability to serve as interpreters of theory to give such interpretation. It is the responsibility of *all* of us to contribute what we can to a broader understanding of both the theory *and* use of statistical quality control. The technical literature of this science will not attain its maximum usefulness if left to a relatively small group of Scribes and Pharisees -- each of us in his own way can make a contribution to this literature by telling our fellow workers about problems we have met, strategy we have used, and results we have obtained. Only, thus can the base of technical publication in statistical quality control be broadened to a point where it will render service it should.

* - *Professor - Northwestern University*
Editor - Industrial Quality Control



APPLICATION OF STATISTICAL TECHNIQUES TO THE PHYSICAL TESTING OF PLASTICS

By: C. R. Adams*

Though Plastics are relatively new engineering materials they are finding many and diversified applications because of their unique physical properties. In the past, present and future, the cut and try technique has been and will be used in determining whether a given plastic material will be suitable for a given application. However, management has always been and is becoming even more aware that this is a costly way of doing business and that many such decisions can and should be based on physical properties data. These data should reflect insofar as possible the magnitude of the property changes due to the variables encountered in the processing, fabricating and normal useful life of a plastic article. Such an objective could formerly be realized only upon the completion of a tremendous testing program. Fortunately, the mathematical statistical techniques, now finding widespread application in industry, can and have reduced the task of studying physical properties of plastics materials. Relegated to the realm of history in the short span of less than a year in our laboratory is the system of conducting a series of tests and interpreting the results without the aid of statistics other than the mean and mean deviation. Experimental or factorial design now precedes all experimental work involving evaluation of the physical properties of plastic materials. The data obtained from this type of experiment can always be statistically analyzed and hence insures that time spent in preparing and testing specimens is utilized to the fullest extent.

We have recently completed two "factorial" design experiments which demonstrate the value of applied statistics in the field of plastics physical testing. One of these was concerned with the Izod impact strength of polystyrene as a function of testing laboratories, specimen notching, testing machines and the manner in which the specimen is mounted in the testing machine. Those sources of variability which contribute to differences among laboratories and within a given laboratory were established. The second experiment was designed to study the injection molding process and the effect of changing temperature, time and pressure upon physical properties in general. Analysis of the data obtained provided, among other things, a reliable indication of which properties are most affected by changes in molding conditions and which variable in the molding process accounts for the greatest overall change in physical properties.

One of the prominent testing machine manufacturers uses the following statement in advertising, "One test is worth a thousand expert opinions --". We interested in plastics physical testing like to apply a new twist and come out with: "One 'factorially' designed physical testing experiment is better than a thousand haphazard tests".

* - *Research Group Leader - Plastics Division*
Monsanto Chemical Company

THE APPLICATION OF QUALITY CONTROL TO THE RUBBER INDUSTRY

By: J. W. Morrison*

"It is most important that top management be quality minded. In the absence of sincere manifestation of interest at the top, little will happen below." J. M. Juran, Management of Inspection and Quality Control.

This statement by Dr. Juran is fundamental. Any Quality Control organization or program, to be effective, must be actively supported by a quality minded top management.

The U.S. Rubber Company policy regarding Quality is illustrated in the statements made by top management people of our organization.

1. "A company can live a year or two without profits, but it cannot live without a quality product." Mr. F. B. Davis Jr., Chairman - Board of Directors.

2. "Quality will always be our top objective. There can be no compromise with the objective of Quality." Mr. T. E. Clark, Factory Manager, Fisk Tire Plant, U.S. Rubber Company.

In conjunction with quality mindedness there must be a sincere expression and belief that Control of Product Quality is necessary and can be successful.

1. "Quality Control is the key to the Tire Division's future". Mr. C. L. Wanamaker, Production Manager of the U.S. Rubber Company.

2. "Statistical Quality Control techniques have not only revealed to us many previously unrecognized causes of variable quality, but have also provided us with the correctives necessary to produce uniformly high quality products at the same or as happened in many cases at a lower cost". Mr. G. H. Cassady, Product Control Manager, Fisk Tire Plant U.S. Rubber Company.

I. A. History of Quality Control in the U.S. Rubber Company.

B. Development of Quality Control Program at Fisk Tire Plant.

1. Statistics on Production, Employment, Etc.,
2. Location of the Quality Control Department, as a staff function.
3. Training courses offered to Production Supervision - Engineering.

II.A. The long range objective of the Quality Control program is to convert tire manufacturing into a truly *precision* industry.

1. Specific application of Quality Control to a rubber processing operations.
 - a. Plastication.
 - b. Banburys.
 - c. Tubing.
 - d. Solutioning - Calendering.
 - e. Equipment in General.
2. Equipment Capabilities and limitations - Instrumentation.
3. Evaluation of Specifications and Tolerances.
4. Time Study Allowances - based on Quality Control data.

III. Quality Evaluation - Statistical Methods.

- A. Quality reports - defect analysis
- B. Inspection - sampling.

IV. Development of supervision and operator interest in Quality Control

A. Techniques available - Quality Refinement Conferences - Merit recognition (Honor Roll) - Quality displays - Effective use of Training Conferences.

V. Benefits Gained by use of Statistical Quality Control at Fisk.

A. Production and Engineering:

1. A better source of information about machine capabilities and limitations.
2. Through statistical analysis, Production has gained a positive source of evaluating machine operators.
3. A constant analysis of stock compounds.
4. A means of minimizing non-uniformity within batches.
5. A simplified, technical method capable of stimulating a quality interest among operators.

B. Inspection Department:

1. Introduction of true random sampling in over-inspection has minimized the number of defective products leaving the plant.
2. Established a competitive spirit among inspectors.
3. Introduced more accurate methods of establishing quality levels.

C. Management

1. Has obtained an impartial referee in the battle of production (man and machinery).
2. An aid in evaluating all new and old machinery in the plant
3. A method of evaluating statistical data never before used by this industry.

These points outlined are only a few of the tangible benefits that have been gained by the use of Statistical Quality Control at Fisk.

VI. The future of the Quality Control Program at Fisk may be summed up in the following eight (8) point program:

The following will be the responsibilities of the Quality Control Group:

1. Devising statistical quality control programs suitable to the industry and its processes.
2. Preparation of charts and procedures in a manner understandable at all levels of production and supervision.
3. Offer results of experiments to those interested in controlling excessive usage and improving methods of operation within their department.
4. Revising present Control programs for improvement or adjustments to see that all applications are paying their way.
5. Provide a source for training of statistical quality control personnel and all interested parties.
6. Aid engineering department by statistically analyzing new equipment.
7. Call attention of Production, Inspection and Engineer-

ing to problems needing their attention as indicated by control charts.

8. Evaluate the quality level of production and issue all reports that make known the quality levels of operation.

- *Product Control Department - U.S. Rubber Co.,
Fisk Tire Division*

NOTES:

STATISTICAL CONTROLS IN A PERISHABLE FOOD INDUSTRY

By: E. Capen Farmer*

Certain exacting requirements peculiar to dairy processing must be born in mind in considering statistical control applications in this industry because they tend to limit the type and scope of control which may be used. These requirements are of two kinds as listed below:

A. Legal and regulatory requirements:

1. U.S. Dept. of Agriculture Market Orders, which govern prices paid for raw milk;
2. Federal and State Pure Food Laws which represent minimum food solids standards and approved labels;
3. State Milk control authorities, which parallel U.S.D.A. market orders as to producers within the state;
4. State and municipal health regulations which set minimum purity, bacteriological, and sanitary standards for plant, personnel, equipment, products, and containers.

B. Unusual process considerations such as;

1. Very large volumes of raw material at a high process rate into all kinds of small containers.
2. Precisely controlled successive high and low processing temperatures and cold storage of product at all stages.
3. Highly perishable, easily contaminated raw material and product.

Many of these apparent drawbacks to setting up statistical controls become, on close study, excellent reasons why they should be highly desirable. For example, food sampling and inspection is necessarily destructive; so the smaller the sample without loss of accurate information, the less inspection waste occurs; and if the statistical method selected is sound, overall risk of waste or spoilage can be greatly reduced.

Our company processes milk into the following lines of finished goods, which we then distribute throughout New England.

- (a) Fluid milk for human consumption.
- (b) Other fluid secondary products, e.g. cream, and flavored milk drinks.

- (c) Condensery manufactured dry, semi-fluid, and fluid products; cheese, etc.,
- (d) Ice Cream.

During the last three years we have adapted statistical methods and/or statistical sampling to the following operations, with a varying individual success but in general achieving sufficient improvement in economical and quality control to encourage continuing and extending our statistical control program.

ICE CREAM PLANTS

1. Weight and fill control charts for virtually all packages in which product is put up.
2. Product yield analysis on certain specialized freezing and automatic filling operations.
3. Raw dairy product receiving control methods for weight, test, and condition.
4. P-Chart control over AOQL of products at most plants.
5. Time series direct labor and equipment productivity charts by days and weeks.

MILK PLANT OPERATIONS

1. Bottle washer solution causticity control charts, (ph concentration during operating time).
2. Paper milk container weight control charts, controlling automatic fill of invisible container contents.
3. Cottage Cheese paper and glass weight and fill control charts.
4. Customer complaint analysis for cause, incidence, geographic or route distribution, etc.
5. Control chart on fillers to locate defective heads.
6. Bottling room labor productivity chart by hours.

COUNTRY RECEIVING AND MANUFACTURING

1. Daily country station - city plant butterfat shortage and quantity control.

2. Country producer payroll vs. city plant butterfat shortage by 15 day periods.
3. Country cream separating control chart over unseparated butterfat in skim milk. (not wholly developed at this time).
4. Cream test standardizing control chart. (experimental)
5. Butterfat loss in spray process dried skim milk powder. (experimental)
6. Receiving labor productivity at country stations. (in development)
7. Accuracy of payroll sampling methods as to producers deliveries of butterfat. (experimental)

EGG DIVISION

1. Candler productivity charts by operators, hours, weeks.
2. Candler efficiency through statistical recheck by certified graders; by operators, days and weeks.
3. Comparative weekly blind scoring of statistical samples for our own and competitors products under market distributing conditions.
4. Incoming dealer and producer egg inspection for percentage off warranted grade, through scoring by reduced sampling.
5. Comparative taste panel testing of our own and competitors products for palatability. (now experimental)

GENERAL APPLICATIONS

1. Vendors goods control for quantity and quality over;
 - (a) Paper containers (ice cream and milk);
 - (b) Bottle caps (milk and milk drinks);
 - (c) Weight control by vendors by type for chocolate products;
 - (d) New Glass bottle breakage due to improper pack or shipment humping etc.
2. Machine variables in processing controls on:
 - (a) Ice cream continuous freezers;

- (b) Temperatures outside of process tolerance (rate of pasteurization, etc.)
- (c) Speed tolerances for moving machinery.
- (d) Refrigeration applications (various).

In addition to the above, we have used statistical control methods as a diagnostic tool for "trouble shooting" a wide variety of variables, both known and unsuspected, which critically affect mechanical efficiency of dairy processing equipment. In some instances this has led to substantial improvements in the equipment itself.

It is impossible in the space available to develop in more detail the uses our company has found for statistical control methods. Our experience to date indicates much experimenting still to be done; but our original conviction that we have been introduced to a "winner" remains unshaken.

* - H. P. Hood & Sons

NOTES:

APPLICATION OF STATISTICAL METHODS IN CHEMICAL FIELDS

By: W. L. Gore*

One of the peculiarities of the Chemical Industry is its dependence on research. Only little is known of the nature of chemical reactions and of the possibilities of chemical combinations. Since there is such a great reservoir of unknown compounds and processes waiting to be discovered, chemical enterprises give a high priority to effort expended in prying loose nature's secrets, and worry less about perfecting current operations which can be expected to be outmoded and degraded to low profit-margin operations in ten, or twenty years. For this reason the great potential of statistical methods in the Chemical Industry lies in the field of scientific research.

Scientific research is just as inefficient without statistical implementation as is sampling inspection. The design of scientific experiments, reduction of scientific data, and tests of scientific hypotheses by experimental results are all problems which are statistical in nature and hence are most efficiently performed by bringing statistical methods to bear on them.

One of the universal problems encountered in scientific work is that of obtaining quantitative measures of phenomena pertinent to the hypothesis involved. Here the statistical approach seems almost an absolute necessity if reliable evaluations of measurement methods are to be obtained. A simple example of the use of statistical methods arose in a recent investigation to improve the control of moisture content in a nylon molding powder. A considerable amount of work had been done by competent but nonstatistical engineers. Odd and wonderful results had been obtained. Moisture had increased during drying processes. High-moisture materials had performed better than low-moisture materials in certain molding tests, while the reverse was true in other tests. It had been necessary to postulate the presence of a mysterious volatile material "X" to account for the strange experimental data obtained. Finally it was decided to seek statistical consultation.

The primary attack on any problem is the reliability of the measurements which are to be made. Even though the moisture analysis method used was rated as accurate with plus or minus 1 unit** (*this rating was based on inference from balance accuracy and duplicate checks run together*), a program was undertaken to evaluate the reliability of the moisture analysis. The factors considered were sampling, analysts, and day of analysis. The experimental results are

shown in Table I.

TABLE I - MOISTURE ANALYSIS OF NYLON

Sample	Analyst						Averages
	A	B	C	D	E	F	
I	15.5	32.2	29.2	36.1	29.0	27.0	I 30.0
	16.5	31.8	28.7	36.0	29.0	26.9	
	(1st day)	(1st day)	(2nd day)	(2nd day)	(3rd day)	(3rd day)	
2	22.0	33.1	35.0	41.5	33.6	27.0	
	22.0	33.0	35.0	40.5	32.4	27.1	
	(4th day)	(4th day)	(6th day)	(6th day)	(5th day)	(5th day)	
1	26.1	32.4	26.0	35.3	30.0	23.1	II 30.3
	25.9	31.7	26.2	34.7	30.0	23.0	
	(1st day)	(1st day)	(2nd day)	(2nd day)	(3rd day)	(3rd day)	
2	20.0	33.1	33.1	41.2	35.1	29.6	
	20.0	32.7	33.0	40.8	35.0	28.5	
	(4th day)	(4th day)	(6th day)	(6th day)	(5th day)	(5th day)	
1	33.2	33.0	25.8	32.4	31.0	24.3	III 32.2
	32.7	33.1	26.3	31.6	30.9	25.6	
	(1st day)	(1st day)	(2nd day)	(2nd day)	(3rd day)	(3rd day)	
2	33.0	33.1	32.2	42.0	35.3	31.7	
	33.0	34.6	32.1	42.0	34.6	30.5	
	(4th day)	(4th day)	(6th day)	(6th day)	(5th day)	(5th day)	
1	21.2	30.0	19.7	34.3	32.6	26.5	IV 30.3
	21.0	30.0	18.3	33.8	31.6	25.5	
	(1st day)	(1st day)	(2nd day)	(2nd day)	(3rd day)	(3rd day)	
2	21.7	38.0	35.6	38.0	37.0	31.6	
	20.4	38.0	34.5	40.0	36.9	30.5	
	(4th day)	(4th day)	(6th day)	(6th day)	(5th day)	(5th day)	
1	21.0	30.2	26.1	34.7	31.4	25.2	V 30.9
	21.1	29.7	24.0	33.5	30.8	24.8	
	(1st day)	(1st day)	(2nd day)	(2nd day)	(3rd day)	(3rd day)	
2	26.0	35.6	36.2	39.5	38.0	32.6	
	26.0	34.5	36.0	38.5	37.8	31.5	
	(4th day)	(4th day)	(6th day)	(6th day)	(5th day)	(5th day)	
Averages:							Grand Averages 30.7

TABLE I (continued)

Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Duplicates for Error	Residual for Error
Analysts	2237.06	5	447.41	1235.9	22.25+
Samples	73.20	4	18.30	50.55+	< 1
Order of analysis	738.55	1	738.55	2040.2	36.73
Duplicates (error?)	21.70	60	0.362	-	< 1
Residual (error)	985.20	49	20.106	55.54	
Total	4055.71	119			

correlation coefficient, day versus moisture = $r = 0.2111$

An analysis indicated that the errors in the method were too large for constructive process improvement work to be undertaken, that the samples increased in moisture on standing, and that the errors between duplicate determinations were not indicative of the true errors inherent in the measurement. Before further work was undertaken it was therefore necessary to develop a more reliable test for moisture, although the sampling technique appeared to be satisfactory within the limits of measurement accuracy.

This is an example of the kind of preliminary experiment which should always be carried out before any attempt is undertaken to examine the more complex aspects of an experimental investigation.

*** All data presented in this paper has been altered.*

** - Research Group Leader - E. I. DuPont de Nemours and Co.,*

NOTES:

STATISTICAL QUALITY CONTROL PROBLEMS IN THE PAPER INDUSTRY

By: Carl E. Noble *

The paper industry possesses elaborate systems for controlling product quality. Efforts to replace or supplement them with systems based upon statistical methods have been only partially successful. There is a reluctance to changing systems which are apparently working satisfactorily. The fact that the applications of statistical quality control to some of the chemical processes have not been as straightforward as similar applications in such industries as the mechanical goods industry has also made difficult the task of the Quality Control Engineer. The conventional control chart methods are not always applicable. For example, where stratification normally exists in a process and the sample from this process is composed of items from all strata, the conventional control chart approach gives action limits which are too wide. In other operations the process average varies under normal conditions to the extent that the conventional approach gives too narrow action limits. These cases necessitate the determination of the variances within and between the strata (*the samples in the latter case*) in order to establish efficient sampling procedures and correct control chart limits.

The problem before the Quality Control Engineer in the paper industry is not the lack of need of statistical methods but that he must frequently use statistical tools which are beyond the scope of the elementary quality control courses. The need for statistical quality control becomes apparent as it is applied to the paper manufacturing operations. One of its most important functions involves showing that the confidence extended the existing control systems is often unjustified as many of these systems are full of pitfalls. A few of these pitfalls will be cited:

1. The failure to convey in a concise form the mass of data from the testing log to the operators and supervisors has greatly reduced the value of the extensive testing. The control charts and other statistical quality reporting systems will perform this function.
2. The concept of sampling and testing errors are often not considered in the present systems. In some cases the error in measurement is sufficiently large to make the small allowable tolerances meaningless. The statistical evaluation of the sampling and testing errors is necessary for the establishment of proper tolerances.
3. A testing program set up without some check upon the

accuracy of the testers is generally of limited value. An efficient check system can be set up only with the knowledge of the errors mentioned above.

4. In a number of the paper manufacturing operations, the sampling must be infrequent. Decisions would be made more cautiously in these operations if the risks involved were known. A system of accumulative analysis, such as sequential analysis, is needed in order to inject adequate sensitivity into the test results.

5. Where variables measurements are impractical, the rating of the product often rests upon the judgement of one or more individuals whose subjective evaluations of quality are based upon definite standards. The introduction of a statistical quality control system constructed upon attributes measurements forces the formation of clearly defined lines between satisfactory and defective quality and furnishes a reliable aid for controlling product quality.

6. In the field of research and development the technically trained individual can expect to gain much if he applies statistical methods to the design of his experiments and to the analysis of the data from these experiments. As a matter of fact, he is stymied in many of his problems if he does not have available techniques for separating such factors as interactions between cause systems and for studying the effects of many variables which change simultaneously in his chemical processes.

* - Technical Control Staff - Kimerly-Clark Corp.,

NOTES:

QUALITY CONTROL METHODS HELP - CARDING, SPINNING, WEAVING
AND INSPECTION OF RAYON AND COTTON TEXTILES

By: R. Hobart Souther*

Variations in the manufacture of textiles have always been a great problem in the industry. It has been shown that the application of statistical methods in Steel, Chemical, Electronics and other industries to control quality during production has resulted in reduced variations in the finished product. Such methods of controlling quality are equally applicable to cotton textiles. The need for this control in in production is evidenced by increased interest in quality control methods in management in all phases of rayon and cotton manufacture.

Close control is not necessary for most textile applications because the majority of textile mills operate on a minimum-requirement basis. However, the minimum and average variability of production should be determined, and a system of quality control charts maintained. Once the control charts get working, the department may expect:

1. An improved product
2. To hold closer tolerances.
3. To help meet specification in delivery of product to next department.
4. Less Seconds and Irregulars.
5. Less samples needed to get proper information.
6. Less destructive tests.
7. Improved quality of work in next department.
8. Improved relationships between department heads.
9. By tagging samples with machine number, to locate source of trouble more quickly.
10. An efficient method of presenting data on break, weight, and other tests, to foreman and superintendent, whereby, they can quickly compare daily tests with those of previous week or month without having to search through piles of record sheets.

This control chart method is based on the fact that by statistical analysis of past data on production, predictions can be made of the variations to be expected in future productions. A control chart is drawn up from records of previous tests on which is plotted upper control limits, average line, and lower control limit. The control limits provide criteria for immediate action to adjust machines or to reject some incoming material. Thus a variation greater than the expected can be checked for cause and an attempt made to eliminate this cause.

Since the control chart is usually a chart of average values, it is necessary to know for purposes of control the range of the individual tests making up the average that has been plotted on the control chart. Therefore, it is advantageous to have a range chart in conjunction with the control chart. The range is defined as the difference between the highest and lowest test figures making up an average. A range chart has upper control limit, average line, and lower control limit, also based on previous records.

Control charts are used for controlling quality during production. In research, too, they can aid in comparing the new method under experiment with the old method or present plant procedure. For example, a card room experiment is run to determine whether a new drafting process would produce more strength in the yarn than the old process. Data from single thread breaking strength tests on the experimental and regular yarns produced in these tests may be plotted on control charts set up for each draft process. When these two charts are compared, differences in strength and uniformity of the yarn is readily seen by comparing the average for strength, and the upper and lower control limits for uniformity. The narrower the control limits, the more uniform is the yarn, and conversely, the wider the control limits, the less uniform is the yarn.

The never ending search for better laboratory evaluations of warp sizing experiments run in the mill resulted in studies of a most original nature in the use of quality control charts to determine differences in the evenness of the size dressings for correlations with weaving qualities of the comparative yarns. By using a novel technique of plotting both average and individual single thread breaks on a quality control chart, both the evenness of the size dressing and expected weavability may be seen at a single glance, as well as the weak spots in the yarn that usually cause the loom stops.

In the textile industry control charts may be used for many evaluating purposes, such as card sliver, drawing sliver, and slubber roving weight tests made in the card room, skein break and count tests in the spinning room, breaking strength of finished cloth, chemical analysis and research tests. Pioneering research is indeed blazing the path of progress and rapidly establishing the value of advancing textiles through statistical evaluations.

- * B.S. in Chemistry - University of North Carolina, Quality Conference - N.C. State College, Chemist - Proximity Manufacturing Company, Chief Chemist - Cone Mills Corp.

NOTE:

SNAPSHOTS OF QUALITY CONTROL AT WORK

By: Paul M. Dickerson*

Specific instances of the application of quality control principles at work in the manufacture of Westinghouse lamps and industrial electronic tubes will be explained. No explanation, however, will be given concerning the fundamentals of control charts or statistical procedure as a knowledge of these tools is presupposed. Also, no attempt will be made to present a "success story" of any sort. Our hope is that those who attend may think of applications of quality control techniques in their own business while we describe a specific problem in control and its solution.

The specific problems to be discussed are outlined below:

I - Parts Manufacture

- A - Metal lamp base strength - an application of distribution chart analysis to the problem of determining from samples what portion of the product is of sub-normal strength.
- B - Glass bulb wall thickness - how minimum limits were established based on the expected roughness of handling and packing quality using a calculated risk of scrapping a good lot.
- C - Ignitor tip characteristic verification - the use of statistical thinking plus common sense to provide a quick but accurate lot by lot verification of firing characteristics of this electronic tube part.

II - Lamp Manufacture

- A - The use of statistical methods to assist in determining the relative accuracy of two laboratories in fluorescent lamp photometry.
- B - Control charts help in securing control of turns per inch in flashed filaments of general lighting lamps and in the foil fill of photoflash lamps.
- C - How control of a hand assembly job involving electrode spacing may be assured when several operators do the same job.

III - Electronic Tube Manufacture

- A - The correlation of ignitor tip characteristics with the final firing voltage of ignitron tubes.

B - Lead weld strength sampled and charted is good insurance against open weld trouble in the hands of the customer.

C - Analysis of life test results using charts assists in measuring the effect of changes in processing.

IV - Evaluation of Quality of a Manufactured Product

A - A tried and proven method of evaluating product quality under the circumstances of both high and low production when many kinds of articles are being produced, each of which can be defective in many ways.

* - *Lamp Division - Westinghouse Electric & Mfg. Co.,*

NOTES:

CONTROLLING SMALL POPULATIONS OF HIGH INDIVIDUAL VALUE

By: A. A. Goodman*

Statistics, as applied to Quality Control, is based on the mathematical theory of probability. Probability, in turn, may well be interpreted as the "law of large numbers". Predominately, publications on Statistical Methods concern themselves with lot sizes that are large; control limits are applied to averages and rarely to individuals; and in addition, the human factor is ignored in setting up control limits.

Therefore, heavy manufacturing producing very small lot sizes, cannot usually employ conventional statistical methods. The value of each item, however, is relatively large and therefore modern control techniques are desirable. Statistical control would, of necessity, be on individualized and extremely small populations. Inasmuch as pure statistical analysis of processes, unique estimating, specialized control charts, and psychological aid, may be employed and satisfactory results obtained.

CASE HISTORY

1. A completely non-automatic machining operation; the operator guides a machine which individually cuts each of ten units per twenty-four hour shift. Tolerances of plus or plus .000 and minus .010 were being exceeded.

2: An unbiased estimate of variance was obtained by plotting individual measurements in a twenty-four hour run. To avoid bias no observations were voided and nine was used as our degree of freedom.

$$\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}}$$

3. σ was .0086, which would result in an anticipated range of .050.

4. The machine operators were taking advantage of a subsequent hand fitting to cover their errors.

5. Control was obviously necessary on the operators and not on the machines.

6. Standard control charts, with UCL and LCL limits were applied. Individual points were plotted immediately after each unit was cut.

7. The psychological impact of the control charts showed results within twenty-four hours. From .0086, σ dropped

to .0009. The operation was in control.

8. Observations since have shown that in individually controlled operations, we can "live" with a larger sigma than would normally be considered safe, due to the estimated R and σ relationship no longer holding entirely true. The variance from \bar{X} is normal only up to the upper and lower control limits; at these points, the human factor becomes significant and tends to keep the operation from exceeding these limits, even though, according to the calculated sigma, we would ordinarily expect to do so.

CASE HISTORY

1. A compound milling operation in which three nested cutters machined five surfaces, two of which were held to plus or minus .0005 tolerances. Two jigs holding thirteen units each were employed. Unreworkable (scrap) defectives were 15.4%.
2. Tests were run for significant variance between tablefuls, between jigfuls and amongst jigfuls.
3. Test between two tablefuls showed negative results.
4. Tests for significance between two jigfuls localized all defective work to one (the left hand) jig.
5. Variance amongst the left hand jigfuls was the predominant cause of the high scrap level. All the scrap work came from the first four positions in the jig. This variance was evidently caused by a too flexible cutter setup.
6. Recommendations were a solid one piece jig cutter, one long jig to hold forty units and climb milling to be employed. Note that the analysis gave the shop a basis for action. That is the important factor - action after the determination of cause.
7. Conventional three color control charts were set up to control the operation and for record purposes. The balance of the order was machined under satisfactory control.

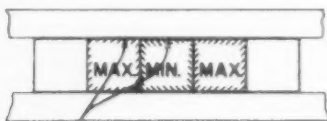
CASE HISTORY

SEE NEXT PAGE FOR ILLUSTRATION OF THIRD CASE HISTORY.

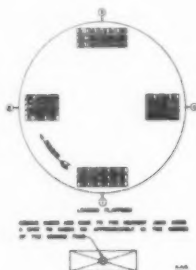
1-WE HAD-



2-WHY WE HAD IT-

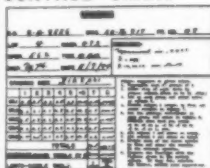


CUTTER LIFTS WORK AND
BREAKS IF THERE IS MORE
THAN .003 DIFFERENTIAL.

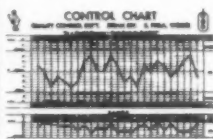
3-ANALYSIS OF PREVIOUS
GRIND TO SIZE OPER-
ATION-

4-WE FOUND-

$\bar{X} = .8126$
 $\sigma = .00056$

5-WE INSTALLED 1st
CONTROL CHART-

$\bar{X} = .8125$
 $\sigma = .00021$

6-WE CURRENTLY
HAVE-

$\bar{X} = .8120$
 $\sigma = .00018$

BREAKAGE
ELIMINATED !

* - Supervisor Quality Control - Steam Division, Westinghouse
Electric and Manufacturing Company

NOTES:

TROUBLE SHOOTING WITH QUALITY CONTROL

By: E. E. Schiesel*

Statistical Quality Control in a job shop, producing upward of a thousand different products for equally as many customers, might well be impossible were the common usages applied. The problems of introducing and using control charts, frequency distributions, and sampling tables into a score of mechanical manufacturing, processing and assembly operations of a conservative New England plant with three generations of "know-how" can be readily imagined. However, Dr. Shewhart's philosophy of control can be and is put to use in the solution of many daily problems that arise in contract manufacturing. In these cases the know-how is quantified and fed back into the plant in the form of better engineering specifications, and relayed to the customer for more complete service.

Actual cases will be used to illustrate the end results of investigations that have brought about the reduction of scrap and rework, the elimination of 100% inspection, and the forecasting of machine tolerances and tool-wear.

The first product investigated statistically in the plant was a throttle rod linkage in a recently retooled popular priced car. The company had produced similar rods for about twenty years without too much difficulty and a minimum of written specifications, but when this product went into production thirty to forty percent of the assemblies were found to be defective. Seven departments contributed to this scrap and rework, each of which was certain beyond a doubt that the other six were totally at fault. In order to investigate the causes, the product was analyzed by means of frequency distributions of random samples at each stage of manufacture. Thus the quality level of each department was evaluated and a basis for remedial action established. Next, a lot was put through normal routine using control chart techniques to check the process capabilities with the print tolerances and to ascertain whether a state of control existed. This information was accumulated and issued to the plant in the form of new specifications, considering the product as a whole, and soon after the product was produced at one-half of one percent defective. The results have been applied to similar products and have provided an entering wedge for statistical thinking in the plant.

The second case illustrates how an expensive 100% sorting operation was eliminated by a study of the processes and a shift in their order. In the preceding case the tolerances at the beginning of manufacture were tightened and as the

product went through subsequent stages were gradually opened until the final assembly matched the customer's specifications.

In the manufacture of compression springs the least accurate stage of the process is the first operation, that of the spring coiler. To reduce variations in length or load, it is necessary to grind, set and test springs in that order. The set and test operation is a combined one and precedent had established it as the least expensive method. However, in the face of competitive bidding it was necessary to reduce the cost by the amount of the inspection operation and the quantity rejected. To quickly test whether this was possible, a coiler was set up to produce the maximum variation in length and load for a hundred samples. Fifty were processed through the time-tested way and about ten percent were found to be over and under specification. The other fifty were set to the compressed height before grinding and the length variation was reduced about 25%. When this lot was ground, the load variation distributed itself well within the specifications. The setting operation was an inexpensive one compared to testing and its cost was borne by the elimination of rejects.

The last case was a simple screw machine brass bushing with tolerances to spare. A test was running to determine the weight per thousand of the piece when it was found that the length varied only 20% of the tolerance and always on the high side. Because it was a small piece the total tolerance amounted to about 10% of the material. Needless to state, the limits were changed to the low side with the resultant saving in raw material. The reason given for the large tolerances was the high speed of production, which made for high tool wear. It was found that this was caused by incorrect setting and the need for machine tending was reduced.

There are many other specific applications of statistical quality control in the job shop, but the underlying motive for these investigations is the quantification of the existing know-how and the successful forecasting of new techniques.

- * - M.E. - Stevens Institute of Technology, M.S. - in Industrial Management - Columbia University, Formerly Production Manager - Slater Electric & Mfg. Company, Woodside, New York, Production Engineer - The Mattutuck Mfg. Company, Waterbury, Connecticut

NOTES:

QUALITY CONTROL AS APPLIED ON FORGINGS IN THE TIMKEN DETROIT AXLE COMPANY PLANTS

By: James Rayer*

Quality control using statistical methods was started in the Timken Detroit Axle Company plants three years ago. The first eight months were devoted to making studies and test applications in machine shops and on assembly floors. The most stubborn problems were attacked first with gratifying results.

September 1946 we inaugurated the system in several production departments. At present 50% of our departments are well covered, with emphasis on critical, major operations. An expansion program is in effect at present. By August first we expect to have our controls established in all departments where measurable values can be determined.

During the first eighteen months a great deal of skepticism existed throughout the organization. The end result we have obtained, however, have convinced everyone, including top management, that quality control is a very worthwhile investment. A completion of our installation program by August first now is a "Management Must".

Control applications in our Forge Plant were started in 1948. In a few months excellent progress was made. The improvements in quality and cost reduction figures are truly amazing.

We have the finest of forging equipment. The supervisory force consists of men with years of experience in manufacturing forgings. Nevertheless we were able, through statistical analysis, to produce more uniform forgings, steel savings amounting to hundreds of tons, tremendous increase in die life, and a substantial reduction in scrap materials. This was accomplished with the use of \bar{X} and R charts, and correlating the finished forging weights with the cutting of billets.

Four control charts plot the accuracy with which cut steel weights or lengths are processed for 343 part numbers. These parts are forged on 16 hammers and 12 headers or upsetters.

Applications of quality control in normalizing of the forged gear blank revealed an uncontrolled process as related to Brinnell hardness. Further studies indicated a change in the normalizing cycle was necessary. These changes resulted in a fine distribution pattern on hardness and a marked improvement in the micro-photographs.

Gleason cutter performance was greatly improved. Normal gear tooth distortion has replaced the abnormal tendency of the past.

Applications of quality control on heat treat furnaces, followed by hardness distribution patterns taken on random samples at final inspection, reduced the overall inspection costs of operation.

STATISTICAL STUDIES VS CONVENTIONAL METHODS

On front axle I beam forgings, a cold straightening operation is required after heat treating to prepare the part for machine operations. Cold straightening these parts is very expensive. Management felt this cost could be reduced with the introduction of an Urschel straightening and quenching machine. Exhaustive studies were required to determine the feasibility of this approach.

Following the Urschel straightening and quench, a draw operation is performed to relieve strains. A study was made of the Urschel quenching accuracy in connection with the amount of change which may take place during the draw operation.

Using conventional methods of inspection in a study of this kind, it is usually the practice to number the pieces consecutively, record the status of each piece, and make individual comparisons after the following operation. the result is an uncontrollable mass of numerical data and true comparison is impossible.

With the statistical approach, we omit the consecutive numbering of pieces and record the same information in the form of a distribution pattern, *one for each operation*. It is then a simple matter to compare the two distribution patterns. The change can be readily detected. For more exacting purposes, standard deviation of each pattern is calculated. Further, the coefficient of variance gives us a true comparison of overall performance.

Our control applications on forgings are by no means completed. Unquestionably further progress will be made as the plan is expanded.

* Author is Superintendent of Inspection and Quality Control of the Timken Detroit Axle Company.

NOTES:

QUALITY CONTROL IN THE AIRCRAFT INDUSTRY

By: John G. Rutherford*

The organization, methods, and philosophy of a Quality Control Department in any industry is dictated, to a considerable extent by:

1. The product produced.
2. The extent of company responsibility for the product.
3. The economics of production

The modern airplane is a highly complex machine. The types of material are numerous and the strength requirements critical. The dimensional and operational requirements for mechanical and functional items are stringent. Any deficiency in material or functional structure, systems and equipment may lead to an operational failure. Therefore, the Quality Control system must economically minimize this possibility.

Any manufacturer of aircraft is responsible for the design and quality of the product during its operational life. This may seem incompatible with the guarantee clause found in most contracts. However, the service problem ends only with retirement of a given model from active use.

The manufacture of an airplane follows the usual manufacturing pattern of design, procurement, manufacture of details, sub-assembly, and final assembly. Any undetected faults in the parts, or the processes producing them can result in costly delays. Building an airplane cannot be compared to a mass-production program, especially in the post-war era. The process is dependent to a large extent on the human factor.

This general picture has led to a pattern of Quality Control organization, methods and philosophy that is fairly uniform throughout the Industry.

Many of the advantages that accrue to the benefit of a manufacturer of a standardized product by repetitive methods are missing. More emphasis must be placed on the screening function.

The use of a statistical methods suffers from limitations imposed by the nature of the product and the method of manufacture. This does not imply that the techniques cannot be used, but rather that they be carefully evaluated in regard to the problem presented by the industry.

Many of the publicized uses of the statistical technique are not economic when applied to aircraft manufacture. Other

fields of application have been completely overlooked or scarcely utilized. Examples of both extreme and conventional applications will be discussed.

Detail aircraft parts are made by successive operations on general purpose machines. Lot sizes are generally small and successive runs are often routed to various machines for the same operations. Under these circumstances the use of machine control charts is not very productive. However, the use of control charts to determine whether shop scrap is abnormal is a useful guide to management.

Repetitive processes, such as the spotwelding of aluminum alloys, have lent themselves well to process control techniques. This method has been adopted in simplified form in an Army-Navy Specification, and is now standard throughout the industry.

Sampling inspection through the use of standard tables and charts is often used on incoming standard parts, on magnetic inspection and on occasional large lots of similar parts produced by a repetitive process. Some Government specifications for the manufacture and inspection of parts contain the specific tables or criteria for the sampling inspection.

In most cases, the normal run of detail aircraft parts screening inspection. The proper provisions for checking can make this a very rapid and inexpensive procedure. Each job, by its nature, dictates the logical method of assurance.

One field of statistical methods that could be very useful has been largely neglected -- the design of experiments and evaluation of data. Problems are at hand in every branch of the industry that would benefit by the application of these techniques. New materials, processes, equipment and requirements are an every-day problem in aircraft manufacture. Their use is predicated on research, test and pilot runs. Elaborate and costly programs are set-up. Data is gathered, classified and then often inadequately utilized or misinterpreted.

Even in the case of time-worn methods, misunderstanding as to the significance of their results often exists. Examples of these will be given.

At the present time, there is the need for a wider spread of statistical concepts through all branches of the industry. There will always be a necessity for the highly-trained specialist. However, from all indications, there would be more accomplished at the right place and at the proper time by an industry alert to the use of statistics as a tool.

- * - CHE Rensselaer Polytechnic Institute, Plant Engineer -
Union Fork & Hoe Company, M.A.E. - New York University,
Assistant Chemical Inspector - Glenn L. Martin Company

NOTES:

SELF HELP BY INDUSTRY ON INSPECTION FOR ARMED SERVICES

By: Ed. Gluck*

Certain difficulties have to be overcome before an Army Representative can accept an invitation to speak. These are that due to decentralization of procurement a speaker representing the Army must confine his remarks to the department he is connected with. In this case, it will be Ordnance. Next comes permission or clearance and last, acceptance is contingent upon the military situation which prevails at time of delivery.

The views and opinions of authorities on the subject of Inspection and Quality Control has been augmented by the experience of many years of the writer with such matters as they pertained to Ordnance work. The writer not only solicits your cooperation with industry but invites criticism.

Meetings similar to the ones held in 1947 at Lehigh University, at New York University in 1948 and now the one here at this Convention keeps alive the importance Inspection and Quality Control plays in a National Military Emergency and likewise emphasizes the importance of Decentralization to Industry in an Industrial Mobilization plan as outlined in a pamphlet issued by the Government June 1, 1948, "A guide for Joint Industry-Military Procurement Planning," and also the one issued by the New York Ordnance District, "Self Help by Contractors at District Level, and Procurement Planning," which outlines responsibilities of the various districts in Inspection matters.

The importance of the adoption of modern Inspection methods and equipment in an Industrial Mobilization plan is stressed by the Army Ordnance Association.

Suggestions to prepare Contractors Planning Manual with the emphasis on Inspection in order to save time, materials, equipment and Inspection personnel. Industry can play an important part in the preparation of such a plan and a well organized Quality Control set up should keep Inspection costs to a minimum as well as avoid waste and time.

As a result of experience in the Last War, much information on Quality Control has developed such schemes as the "Grand-Lot" system (An Ordnance Discovery) the single and double sampling plan and many others.

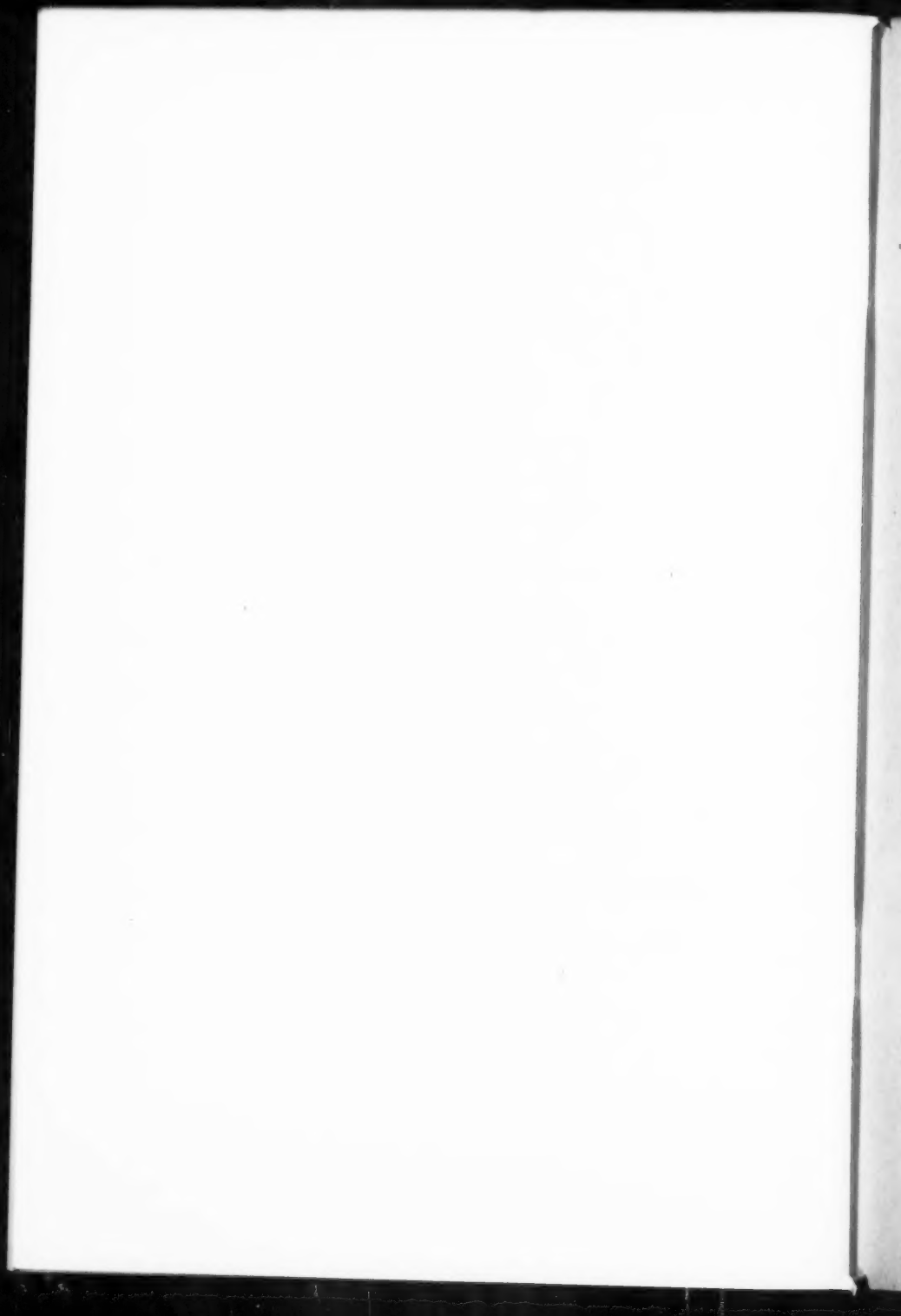
The Ordnance Department and Ordnance Districts are constantly issuing pamphlets on this subject for the purpose of increasing efficiency time and waste and the proper allocation of re-

sponsibility. The use of records and statistics is essential and is constantly being stressed.

An analysis of the present situation brings out the fact that in the event of a National Emergency, Personnel will be lacking with particular reference to high-grade Technicians and Engineers and Self Help by Industry on Inspection for the Armed Forces is essential.

* - Lt. Col. - Deputy Chief, New York Ordnance District
Order Department - U. S. Army

NOTES:





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